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THE HOME OF THE RODENTS.

By R. LYDEKKER, B.A.Cantab., F.R.S.

RANGING over all the continents and most of the islands of the globe, and being represented even in marsupial-inhabited Australia, the rodents, or gnawing mammals, form such a thoroughly cosmopolitan group that it seems, at first sight, almost illogical to speak of one country more than another as being their home. Nevertheless, in the course of the present article we hope to be able to convince the reader that South America—whether we take into consideration the tropical forests of Brazil, the grassy plains of Argentina, or the desert wastes of Patagonia—has an undoubted claim to the title in question. We may add, however, that under the name South America we include both Central America and the West Indies, the whole of which form one zoological province.

In a previous article we have had occasion to allude to the chief peculiarities of the fauna of South America, and it was there stated that among the most characteristic forms of mammals were edentates, opossums, marmosets, and the New World monkeys, together with numerous rodents. It did not, however, come within the province of that article to take the latter group into detailed consideration, but as this is a subject of much interest from a distributional point of view, it may well form the theme of a separate essay. Probably the majority of our readers know what is meant by a rodent, or gnawing mammal; but should there be some among them whose ideas are somewhat hazy on this subject, it is to be hoped that their more learned brethren will pardon a few words in regard to the characteristics of the creatures in question.

As common and well-known examples of the rodent order we may cite squirrels, dormice, marmots, beavers, rats, voles, porcupines, and hares and rabbits, all of which are characterized by possessing a pair of chisel-shaped teeth in the front of each jaw, which are worn by use into a sharp, cutting, transverse ridge, and grow continuously throughout the life of their owners. It is with these chisel-like front or incisor teeth that the rodents perform that gnawing action (so markedly developed in the beavers and porcupines) from which they derive their name; and it is owing to the circumstance that the front of each tooth is faced with a plate of hard enamel, while the remainder consists of soft ivory, that these beautiful instruments maintain their cutting edges. These two pairs of front teeth are absolutely characteristic of all rodents, and in by far the greater majority of the order there are no other teeth in this region of the jaw. As if, however, for the purpose of hinting to us how these animals were originally related to mammals provided with a fuller set of teeth, the hares and rabbits, together with their near allies the picas or tailless hares, have a minute pair of somewhat similar teeth placed immediately behind the large pair in the upper jaw. Being perfectly useless to their owners, this second pair of upper front teeth evidently comes under the category of rudimental or vestigiary structures. Behind the front teeth of all rodents comes a long gap in each jaw, after which we reach the series of grinding or cheek-teeth, which are never more than six in number, and are frequently reduced to four, or even three. Consequently, no member of the order ever has tusks or canine teeth. Were it not that there are two groups of animals with a dentition of a similar type, these peculiarities in the teeth would absolutely distinguish rodents from all other members of the mammalian class. Of the groups in question, the one contains the wombats of Australia, which are broadly distinguished by the presence of a pouch for the young, while the second group is represented solely by the curious aye-aye of Madagascar, which agrees in its internal anatomy with the lemurs, and is accordingly assigned by naturalists to that group. With these exceptions, the dentition is absolutely characteristic of the rodent order; and as the reader is not likely to confound with them either of the creatures named, he may rely on the nature of the teeth in identifying the members of the order under consideration.

Having thus settled what constitutes a rodent, our next point is the classification of the order; for until we gain some insight into this, it is quite impossible to understand the especial richness of South America in regard to these animals. Rodents, then, are divided by naturalists into seventeen families, several of which are brigaded together into a small number of larger groups. Of these groups, the first is the squirrel-like rodents, which includes the four families of the African flying squirrels (*Anomaluridæ*), the squirrels and marmots (*Sciuridæ*), the sewellels (*Haplodontidæ*), and the beavers (*Castoridæ*). Now, of these four families, the only one occurring in South America is the second, and its representatives there are merely certain species of squirrels, which, moreover, do not range south of Paraguay; the whole of the marmots, prairie-dogs, susliks, chipmunks, etc., being totally unknown south of the Isthmus of Darien.

The second great group of the order, known as the mouse-like rodents, includes five families—namely, the

dormice (*Myoxidæ*), the jumping mice and jerboas (*Dipodidæ*), the whole great mouse-tribe (*Muridæ*), as represented by mice, rats, voles, hamsters, and their kin; the mole-rats (*Spalacidæ*), and the American pouched rats (*Geomyidæ*). Of these, the only one represented in South America is the cosmopolitan mouse family. In this group, however, the true rats and mice of the Old World are totally wanting (except through involuntary introduction by man) as indeed they are throughout the New World; their place being taken by the white-footed mice, common both to North and South America, and nearly allied to the hamsters. In addition to these, there are a few genera belonging to the family which are quite peculiar to South America, one of the best known of these being the groove-toothed mice (*Rhithrodon*), a representative of which extends as far south as Tierra del Fuego.

Fig. 1.—Upper Surface of the Lower Jaw of the Coypu, to show the chisel-like front teeth and the grinding molars.

By this time the reader will probably begin to think that, instead of South America being the home of the rodents, it is precisely the country where those animals are rarest, seeing that out of the nine families noticed above only two are represented there at all, and both of these somewhat poorly. His opinion will, however, at once change when we have considered the third great group of the order, which may be known as the porcupine-like rodents. The members of this group are readily distinguished from those of both the preceding sections by the structure of the lower jaw, although this difference can, of course, only be seen in the skeleton. Whereas in both the squirrel-like and mouse-like sections the hinder lower projection of the lower jaw, technically known as the angle, takes its origin from the inferior edge of the socket for the lower chisel-like teeth, in the present group the same projection arises from a prominent ridge running along the side of the jaw itself, as shown in Fig. 1. Of the six families into which the porcupine-like rodents are divided, four are exclusively confined to South America, while the fifth (*Octodontidæ*) is mainly South American and West Indian, although with a few representatives in Africa south of the Sahara desert. On the other hand, the porcupine family (*Hystricidæ*) is almost cosmopolitan, although the American representatives are so distinct from their Old World allies as to form a separate sub-family; while of the three genera constituting the latter, one is North American, and the others are mainly South American, although one has a single species ranging as far north as Mexico. Of the last group of the order, namely, the hare-like rodents, as represented by the hares and rabbits (*Leporidæ*) and the picas (*Lagomyidæ*), we have but little to say, seeing that its occurrence in South America is limited to two species of hares.

It will thus be seen that, out of a total of seventeen families, nine are represented in South America; and of these nine, four are absolutely peculiar to that country and the adjacent islands and isthmus, while a fifth has representatives elsewhere only in Africa, and a sixth (the porcupines) has two genera which are practically only South American, and are distinguished from all their allies by their prehensile tails. The significance of these remarkable facts in geographical distribution will be made apparent when we state that, of the other great zoological regions into which the globe has been mapped out, there are only two which have any families of rodents peculiar to them, the maximum number of such peculiar families being two. Thus Africa south of the Sahara, constituting the Ethiopian region of zoologists, has the African flying squirrels, which are nearly allied to the true squirrels, and are represented only by a single genus, with a comparatively small number of species; while North America, or the Nearctic region, has the sewellels, with one genus, and the pouched rats, with five.

Before entering on the significance of these facts, we must devote a short space to the consideration of some of the more remarkable of the South American types of porcupine-like rodents, by which alone the reader will be enabled to appreciate their peculiarities and numbers. Commencing with those families which are confined to the Neotropical region, as zoologists term South America, together with Central America and the West Indies, we have first of all the cavies (*Caviidæ*), which are heavily-built rodents, with four front and three hind toes, rudimental or short tails, and the molars divided by transverse folds of enamel into a number of thin plates lying parallel to one another, after the fashion shown in Fig. 2. The typical representatives of the family are the true cavies (*Cavia*), of which the guinea-pig is a domesticated descendant, having assumed a coloration quite different from the uniform olive-brown tint characteristic of its wild ancestors. Quizos, as these animals are called in the Argentine, may be found not only among aquatic plants in marshy districts, and skulking in the tufts of coarse grass on the pampas, but in the neighbourhood of human habitations will not unfrequently take up their residence

under the floors of out-buildings, whence they issue forth to feed at night. All the true cavies are small and short-legged creatures; but the Patagonian cavy, representing the genus *Dolichotis*, is a much larger and taller animal, measuring nearly a yard in length, and standing over a foot at the shoulder. An inhabitant of the open districts of Patagonia and Argentina, the mara, as it is called by the natives, much resembles a hare in its movements. Unfortunately, the spread of cultivation has well-nigh exterminated this handsome rodent from most parts of the Argentine. Largest, not only among South American rodents, but likewise in the entire order, is the aquatic carpincho or capivara (*Hydrochærus*), attaining a length of upwards of four feet. The most remarkable peculiarity of this animal is the large size and complex structure of the last molar tooth, which in the upper jaw may have as many as twelve plates, and is comparable in structure to the corresponding tooth of the Indian elephant. The carpincho is an inhabitant of the more tropical districts, not extending southwards of Uruguay. Nearly allied are the agutis (*Dasyprocta*) and pacas (*Cœlogenys*), collectively constituting the family *Dasyproctidæ*, which differ from the cavies in that the folds of enamel only form notches on the sides of the crowns of the cheek-teeth. The agutis are rather delicately-built animals, ranging from the confines of Mexico to Paraguay, and represented by an outlying species in the West Indies. The pacas, with nearly the same distribution, are, on the other hand, much larger and more heavily-built animals, characterized by the longitudinal rows of light-coloured spots on the fur, and the large bony capsules formed by the expanded cheek-bones.

FIG. 2.—Upper Surface of the Lower Jaw of a young Viscacha. The hinder part of the left branch is broken off.

Another family (*Chinchillidæ*) is represented by the beautiful little chinchillas (*Chinchilla*) of the Andes, so esteemed on account of the marvellous softness of their pearly grey fur; by the much larger Cuvier's chinchilla (*Lagidium*), which is also an inhabitant of the Andes; and likewise by the well-known viscacha (*Lagostomus*) which lives in warrens in the Argentine pampas, and is remarkable for the habit of collecting all kinds of odds and ends round the entrance of its burrows. From the similarity of its habits, the viscacha is commonly believed to be a near ally of the marmot, with which, however, it has no close affinity. All the members of the family have long, bushy tails, very soft fur, elongated hind limbs, and the molar teeth divided by complete transverse folds of enamel into plates, as shown in Fig. 2. Sufficiently distinguished by their spiny covering, the porcupines (*Hystricidæ*) are represented in South America by two arboreal genera (*Synetheres* and *Chætomys*), differing from all their allies by their prehensile tails.

The largest of all the families under consideration is that of the octodonts (*Octodontidæ*) which, as already mentioned, has representatives in Africa, although the majority of the forms are South American and West Indian. In addition to other characteristics, these rodents have the crowns of the molar teeth marked by infoldings of enamel on both sides (Fig. 1), while there are generally five toes to each foot. In form they are generally more or less rat-like. Unfortunately, our limits of space permit only of a very brief reference to these forms. The typical representative is the degu (*Octodon*) of Chili and Peru, which is a rat-like animal with a long tail tipped with a brush. Other species inhabit Bolivia, which is also the home of certain allied rodents (*Habrocoma*) remarkable for having fur nearly as soft as that of the chinchillas. Nearly related are the burrowing tuco-tucos (*Ctenomys*) of South America, deriving their popular title from the bell-like cry uttered as they work beneath the soil, and their scientific name from the comb-like bristles with which the hind feet are furnished.

Passing over some smaller types, our next form is the coypu (*Myopotamus*), which is a large aquatic form, with beaver-like habits, found on both sides of South America, and commonly known as the nutria. Remarkable for the bright red hue of its front teeth, the coypu, except for its tail, is not unlike a beaver in general appearance, and is commonly regarded by settlers in the Argentine as a near ally of that rodent. In the West Indies the family is represented by the large arboreal forms known as hutias, most of which are included in one genus (*Capromys*); although, on account of the complex structure of its molars, one kind from Hayti and Jamaica is separated as *Plagiodon*. These animals may be compared to gigantic rats, one of them measuring twenty-two inches exclusive of the tail. Six other genera are also found in South America, most of them being smaller rat-like forms, in some cases (*Echinomys* and *Loncheres*) characterized by the admixture of flattened, lance-like spines among the fur.

Limits of space preclude any mention of the mouse-like members of the order peculiar to South America, and this omission is of less importance since it is not improbable that these forms are later immigrants from the north. Sufficient has, however, been said to show how extremely peculiar and numerous are the rodents of the Neotropical region, the whole of the genera belonging to the porcupine-like group found in that part of the world being absolutely confined to it, and the same being the case with several of the families. Not only are these rodents remarkable for the number of genera and species by which they are represented, but they are likewise noticeable for the large dimensions which many of them attain. Geological investigations have shown that allied rodents—one of which is stated to have attained dimensions equal to those of an ox—inhabited Patagonia during the middle portion of the Tertiary period, contemporaneously with the extraordinary ungulates alluded to in a previous article. It is, therefore, evident that all these mammals must have obtained entrance into South America contemporaneously, while they developed side by side during the period it was cut off from the northern half of the continent. What was the exact connection between these South American rodents and the allied African genera is at present uncertain, but there are many facts which point to a former

intimate relationship between the faunas of all the southern continents, and their isolation from those of the northern half of the world.

NOTE.—In the September number of KNOWLEDGE, two wood-cuts illustrating Mr. Lydekker's paper on "The Ancient Mammals of Britain" have been transposed. Fig. 1 should be "last upper molar tooth of the Hyænarctus," and Fig. 2 should be "right upper molar tooth of Steno's Horse."

THE BACTERIA OF PHOSPHORESCENCE.

By C. A. MITCHELL, B.A.Oxon.

THAT the flesh of certain animals, especially marine fishes, could often exhibit the phenomenon of spontaneous light was noticed as long ago as the days of Aristotle, but it is only within the present generation that the true cause has been made known.

In 1676, a Dr. Beale, of Yeavil, in Staffordshire, published in the *Philosophical Transactions* of the Royal Society a curious instance of the kind, and mentioned as a possible explanation that the stars were exceedingly bright on that night, and the weather warm and gentle. A woman of that town had bought a neck of veal, which seemed perfectly good in every respect. On the following evening, about nine o'clock, the neck of veal "shined so brightly that it did put the woman into great affrightment." She roused her husband, and he seeing whence the light proceeded endeavoured to extinguish it by beating the veal, and eventually plunging it below water; but in vain. At last he found he could extinguish the light by wiping the meat with a cloth. The next day the joint was cooked, and certain neighbours who had seen it giving light were invited to partake of it. All esteemed it as good as any they had eaten.

Many similar cases of meat becoming phosphorescent are on record. In 1492 it was a frequent occurrence in Padua, and during the early years of last century it became so prevalent in Orleans that several butchers were almost ruined, since their customers considered such meat unfit for food, and much of it was thrown into the river.* Coming to the present day, Nuesch describes how the whole of the meat in a butcher's shop became luminous in one night.

The first recorded experiments to determine the cause of such cases were made by Dr. Hulme in 1800, and from his results he was led to conclude:—

1. That putrefaction was not the cause, for as decay advanced the light gradually decreased. Moreover, in the case of phosphorescent meat there was no offensive smell.

2. That spontaneous light was a constitutional principle of some bodies, incorporated with their whole substance just as any other principle, and that it was probably the first principle that escaped after the death of marine fishes.

This plausible solution has since been displaced by the discovery that bacteria were invariably present in phosphorescent sea-water and on phosphorescent meat, and that directly or indirectly the light was due to their agency.

Bacteria is the generic term applied to certain low forms of vegetable life. They multiply by dividing up or "fission," and some also by the formation of spores. The *yeasts*, which increase by budding, are accordingly not bacteria, though they are sometimes classed with them. Bacteria are classified in two main groups:—*Coccaceæ* or spherical forms, and *Bacteriaceæ* or rod-shaped forms. To the latter belong the *bacteria* proper, straight rod forms in which spore formation is not known to occur; the *bacilli*, straight rod forms which form spores; and the *spirilla*, twisted forms not forming spores.

An artificial growth of these on nutrient gelatine, or some other suitable medium, is called a colony, and consists of a mass of the organisms. The appearance of the colony, which is often characteristic, is of importance in identifying the species of micro-organism of which it is composed.

At least six species of light-producing micro-organisms have been described, each having different properties by which they may be distinguished from one another. They all belong to the *bacteria* proper, though, from their length and breadth being often nearly the same, they have occasionally been described as members of the *Coccaceæ*. They fall naturally into two groups, of which the first includes the four following species:—(1) *Bacterium phosphorescens*, a motile organism pretty widely distributed; its average size is $1{\cdot}7\ \mu$† long by $1{\cdot}5\ \mu$ in breadth; (2) *Bacterium Pflügeri*, an organism about the same size as the preceding. It has rounded ends, and dividing rapidly, the cells usually appear almost round. It is the usual cause of the phosphorescence often observed on herrings and mackerel. (3) *Bacterium Fischeri*, and (4) *Bacterium balticum*, two species of similar size and form. They do not cause any fermentation as the first two do. All these may be grown on nutrient gelatine without causing it to become liquid; but for their successful cultivation they require the presence of the albuminoid substance *peptone*, and another carbon compound, such as glycerine or glucose.

In the second group are (1) *Bacterium indicum*, a motile rod of medium size, found in West Indian waters, and (2) *Bacterium luminosum*, the cells of which are shorter than those of the preceding bacterium. It occurs in the waters of the North Sea. These two species are able to flourish on *peptone* alone, and cause rapid liquefaction when grown on nutrient gelatine.

With regard to the conditions under which these various micro-organisms can produce light, it has been found that temperature has a good deal of influence. According to Ludwig, a piece of meat remained luminous as low as $-14°$.‡ Heated gently in a tube over a water-bath it was still phosphorescent at 30°, but at 40° had ceased to emit light. *Bacterium phosphorescens* thrives best between 15° and 25°, but Tilanus and Förster proved that it could live below zero. When kept at 35° for a few minutes its luminosity disappeared, but on cooling returned. If, however, it was kept at that temperature for fifteen minutes its power of producing light was permanently lost.

The other organisms show a difference in this respect. *B. Fischeri* gives no light at a temperature above 25°, while *B. indicum*, which thrives best at 30°, cannot grow below 15°. *B. luminosum*, on the other hand, is most luminous at 15°.

There is also a difference in the character and intensity of the light produced by the various species. *B. phosphorescens* gives out a greenish-yellow light, while that produced by *B. Pflügeri* is bluish-white and far more intense. By exposing a sensitive plate in an otherwise completely dark room, Förster succeeded in obtaining a photograph of a colony of this species by means of its own light. Fischer was able to do the same with colonies of *B. indicum*. It is, therefore, not surprising to learn that Ludwig, who examined spectroscopically the light produced by *B. Pflügeri*, obtained a spectrum rich in violet rays.

* "Lemery of Chymistry," 1720.

† $1\ \mu = \frac{1}{1000000}$th part of a metre $= \frac{1}{25000}$th of an inch.

‡ All the degrees of temperature are on the Centigrade scale. To convert into Fahrenheit, multiply the number of degrees by 1·8, and add 32 to the product.

As to the manner in which the bacteria produce the light, there is still much research needed. As Hulme found in 1800 (and his observation has since been repeatedly confirmed) putrefaction does not assist phosphorescence. The light-producing bacteria are unable to do their work in a substance on which the putrefactive organisms are growing, and as soon as decay is fairly advanced the light altogether ceases.

The presence of oxygen appears to be an essential, for colonies will only give light on the surface of the culture medium, where they can have free contact with the atmospheric oxygen. This gas, however, is not essential for the life of the bacteria. They will grow in an atmosphere of hydrogen or carbonic acid gas, but under such conditions will not produce light.

Apparently it is not necessary for the colonies to be grown in the light of the sun, for cultivations made in complete darkness have been found to emit light as readily as those grown in daylight.

It has been suggested by Lehmann and Tollhausen that the light is produced by some molecular change within the cells of the bacteria—a sort of vital process—and the fact that all chemical reagents which destroy the protoplasm of the cell simultaneously stop the luminosity, lends some support to this theory. Thus, mineral acids, alkalies, and various disinfectants which are fatal to the bacteria, effectually destroy the phosphorescence produced by them. As was mentioned before, heat and cold have a similar effect.

An equally plausible theory, however, is that just as some bacteria produce ptomaines and albumoses, and others colouring matter, so the light-producing bacteria may produce substances with their molecules so arranged that we have the phenomenon of phosphorescence. If this be so, it is probable also that these products are readily affected by heat and chemical agents, and that then a fresh arrangement of the molecules takes place, and the substances lose their luminous properties. The experiments of Dubois* on the luminous mollusc *Pholas dactylus* tend by analogy to support this. From its luminous mantle he extracted two phosphorescent crystalline substances, to one of which he gave the name of *luciferase*. It was to these substances, which it secreted, he considered that the fish owed its luminosity.

When it has been decided whether the bacteria are in themselves phosphorescent, or whether they are so only by virtue of their products, there will still remain the further problem of the nature of the phosphorescence itself.

THE DADDY-LONGLEGS.

By E. A. Butler, B.A., B.Sc.

THE advancing autumn has brought with it the usual visitation of swarms of "daddy-longlegs," and it will no doubt be acceptable to the readers of Knowledge if we take the opportunity, while the discomforts of the visitation are still fresh in the mind, of setting before them an account of these fragile but none the less troublesome insects. The chief cause of the inconvenience to which they subject us in their adult state is the awkward way in which they tumble about, blundering up against us with the tickling sensation of buzzing wings and straggling legs, or immolating themselves in the gas or lamp flame, and startlingly dropping their singed and mutilated bodies on to the page which we may happen to be reading or writing. But, as we have had occasion to remark before, it often happens that the most harmful period of an insect's life is not that which is most prominently before human eyes; the greatest damage wrought by an insect pest is often done in secret, when the real cause of the injuries is generally unsuspected. Such is the case with the insect now before us, for the inconvenience caused during its period of publicity is as nothing compared with the havoc wrought by it during its earlier life of seclusion, when its aspect is so different from that of the well-known "daddy" that none who were not in the secret would suspect the identity of the two insects.

The "daddy-longlegs" with which we are most familiar is but one species of a large group, the family *Tipulidæ*, and of one very extensive genus in that family, the typical genus *Tipula*. Thus the name "daddy-longlegs" is, strictly speaking, not a specific designation, but a general term, and there are large numbers of insects to which it may be, and is, equally appropriately applied. Still, it is no doubt a single species which is usually understood by the term—a greyish-brown fly, with semi-transparent wings, the brown nervures of which stand out distinctly on the lighter background. The thorax is hoary beneath, and the six long legs are brown at the base and blackish towards the tip. To this species the name *Tipula oleracea* has been given. The great length and slenderness of legs in these creatures has recalled the corresponding feature in wading birds, and has led to their getting the name of "crane-flies." In France they are known as "tailors" and "seamstresses." The great length of legs is not altogether disproportionate; it finds correlated characters in the other parts of the body, and is no doubt of some assistance to the insects in walking in the grassy places that form their principal habitat.

We may now endeavour to get such an exact notion of the form and structure of our crane-fly as will be obtained by a close examination, assisted by the use of a hand-lens of low power. The single pair of wings marks it out as a dipterous insect, and we may at once notice that the wings are usually carried, when at rest, not folded together over the body, as would be the case with most flies, but widely open and slightly elevated on each side, as though to be ready for use at a moment's notice. Their extreme narrowness at the base, as well as for some distance along their length, is indicative of that feebleness of flight for which the insects are noted—a feebleness which is, however, perfectly compatible with a rapid and rattling vibration of the wings.

If this wing be compared with that of a strong flier, such as a bluebottle, a striking difference is seen. The bluebottle's wing is furnished with a sort of extra flap of membrane at its base, which, when the wing is extended, fills up the space between its broader part and the body; while in the crane-fly this space is quite open and unoccupied with membrane. This appendage to the true wing is called the "alula" or winglet. Projecting from the hinder part of the thorax into this open space is, on each side, a delicate little organ, the so-called "balancer," a sort of clubbed stalk, whose intimate structure is well worth careful study. Now it is a curious fact that in the two flies we have mentioned, these two parts, the winglets and balancers, appear in inverse ratio of size. The strong and vigorous bluebottle, which has a very large winglet of most exquisite structure, has a completely insignificant balancer, which requires close search to discover it at all; whereas the weakling crane-fly has no trace of a winglet, but has proportionately the largest balancer that is to be found amongst British Diptera. And this is only one

* Soc. de Bio., *Comptes rendus*, 1887.

XUM

illustration of the law of correlation of structures, of which many others may be observed in the same two insects. Consider, for example, the following details of symmetry and contrast: in the vigorous and active bluebottle we find a stout, heavy body, short legs, short, strong wings with large alulæ, a short compact head, insignificant balancers, and a body beset with stout bristles. In the fragile and weakly crane-fly all these points are reversed, and we find a long, slender, light body, very long legs, long narrow wings without alulæ, a long and tapering head, large and conspicuous balancers, and a smooth and bristleless body.

The shape of the thorax, strongly convex and humpbacked above, is worthy of notice, as representing in an almost exaggerated degree the general plan of dipterous structure in that part of the body. Remembering that each of the three pairs of legs represents a separate division or segment of the thorax, it will be comparatively easy to trace the limits of these regions, by following the junctions upwards from the points of attachment of the legs. It will thus be seen that the prothorax, or first region, is reduced to very small dimensions, forming no more than a sort of collar, just behind the head. The metathorax, or third division, a much larger mass, will be found behind; but when we have marked off these two parts, there still remains the greater portion of the thoracic mass, which is thus proved to belong to the second segment, or mesothorax. If we bear in mind that this is the division which, in insects generally, carries the fore wings, and that in flies the fore wings are the only pair developed, the reason for the great development of this part will be at once evident, for within its cavity are stored the muscles that are instrumental in working the wings. There is one feature of the mesothorax that is specially characteristic of the family we are now considering, a trivial feature no doubt, but one which is helpful in distinguishing *Tipulidæ* from other groups. Across the middle of the upper surface runs a V-shaped furrow, which is not to be found in other groups of flies, for the rest of the order either have a smooth surface here, or if a transverse impression is present, it is incomplete and not V-shaped. At each side of the thorax will be seen two narrow slits, one just above and behind the insertion of the first pair of legs, and the other at the base of the balancers. These are two of the spiracles, or entrances to the breathing tubes, which, as with insects generally, traverse all parts of the body and convey air to the system at large.

The head (Fig. 1) is most peculiar in shape, being prolonged into a sort of beak. The basal part is almost globular, and the compound eyes occupy a large part of the surface here. In life they are of a bright green colour, a very pleasing relief to the sombre tints of the rest of the body; unfortunately, however, the colour is fleeting, and passes away after death. At the end of the beak are two jointed organs, which, when not in use, are carried bent back underneath the head; these are the maxillary palpi. The upper part of the head carries the antennæ, a pair of long, jointed, tapering organs, with circles of delicate bristles at the junctions of the joints. The form of the antennæ decides at once to which of the two great divisions of flies the crane-fly belongs, viz., the Nemocera, or "thread horns." This, again, is another respect in which it differs markedly from the bluebottle and other flies of that robust type, which have short and most oddly-shaped antennæ. It is hardly necessary to say that no biting jaws exist in the perfect insect. No power of biting or piercing is possessed by it, and hence its harmlessness in this stage, whether to man, beast or plant.

Fig. 1.—Head of Daddy-longlegs.

The legs, as already mentioned, are exceedingly long and slender, each of the divisions being elongated to a considerable extent; the tarsi, or feet, which are five-jointed, with the joints diminishing in length as they recede from the body, are even longer than the tibiæ. They are not only long and slender, but also very fragile and easily broken off, an accident to which the insects are extremely liable, but at the same time one which cannot be regarded as of a serious character, for the loss of even half the number of its legs does not prevent the insect from going about its business as though nothing had happened. Such losses can hardly be attended with much pain, and their chief influence would no doubt be felt in the difficulties in steering during flight, which would follow. Unlike crabs and lobsters, the daddy-longlegs does not possess the power of reproducing a lost limb, nor indeed would the power be of any avail if it existed, since the insect's adult life is too short to allow time for any such restored limb to grow.

Fig. 2.—Ovipositor of Daddy-longlegs.

The hinder part of the body differs markedly in the two sexes. In the male it is blunt and swollen, the enlarged part containing a complex reproductive apparatus; but in the female, it tapers regularly to a hard and sharp point. This acute tip (Fig. 2) is the hardest part of the body, and necessarily so, as it has to do the hardest work, and indeed the only serious work that devolves upon the fully-matured insect. It constitutes an egg-laying instrument of superior quality, and is composed of four pieces disposed in pairs. On the upper side are two long and pointed pieces which form the sharp tip, and are used as borers, and underneath these is the other pair, considerably shorter, broader, and blunter, their function being to guide the eggs in their passage into the hole prepared for them by the pair of borers. The whole apparatus, therefore, is something like a combination of an auger and a spoon.

The eggs are small, shining black, and slightly curved. When they are about to be laid, the mother insect behaves in a most remarkable manner—in a manner, indeed, that might have been thought impossible had it not been actually witnessed. It will be remembered that in those animals in which a distinct longitudinal axis of the body can be traced—such, for example, as vertebrates and arthropods—the almost universal position of that axis is horizontal, the chief exceptions being man and birds, whose use of only one pair of limbs in walking throws their axis into an erect or sloping position. So in insects and other arthropods, as the bipedal arrangement does not exist, one naturally expects to find the axis of the body placed horizontally when the animal is walking over a level surface, and in fact it is a most exceptional circumstance that any other disposition should occur. When, therefore, it turns out that the female daddy-longlegs, on its egg-laying expedition, actually struts about on its hind legs with its body placed in a perfectly erect position (Fig. 3), it will be admitted that we are justified in considering this most extraordinary behaviour. Considering the structure of the legs, however, it is evident that the proper balancing of the creature, if it had to depend on its hind legs only, would be a somewhat nice operation, and hence the pointed abdomen is requisitioned as an auxiliary, and is used as a third prop. Most ludicrous is the sight as

the insect, rearing itself perfectly erect, and flourishing its four front legs in the air, goes hobbling along on its tripod, prodding its pointed body into the ground at every step, while the legs bend like springs as it does so. Such a sight may often be seen in the proper season on damp grassy spots where the insects are plentiful, and they may be watched with ease, for there is no fear of their shyly retiring from observation, since they are far too intent on their work to notice the presence of an intruder.

When a suitable spot has been found, the ovipositor is plunged into the ground and kept there while several eggs

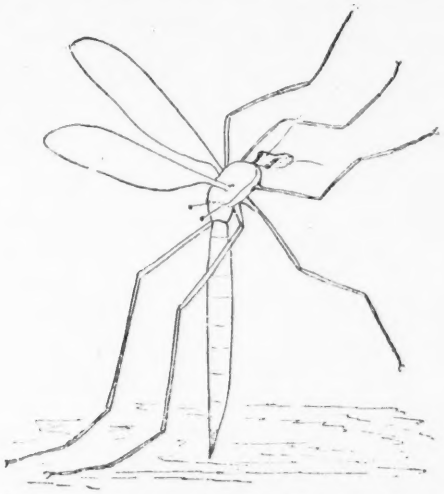


Fig. 3.—Attitude of female Daddy-longlegs, when on an egg-laying expedition.

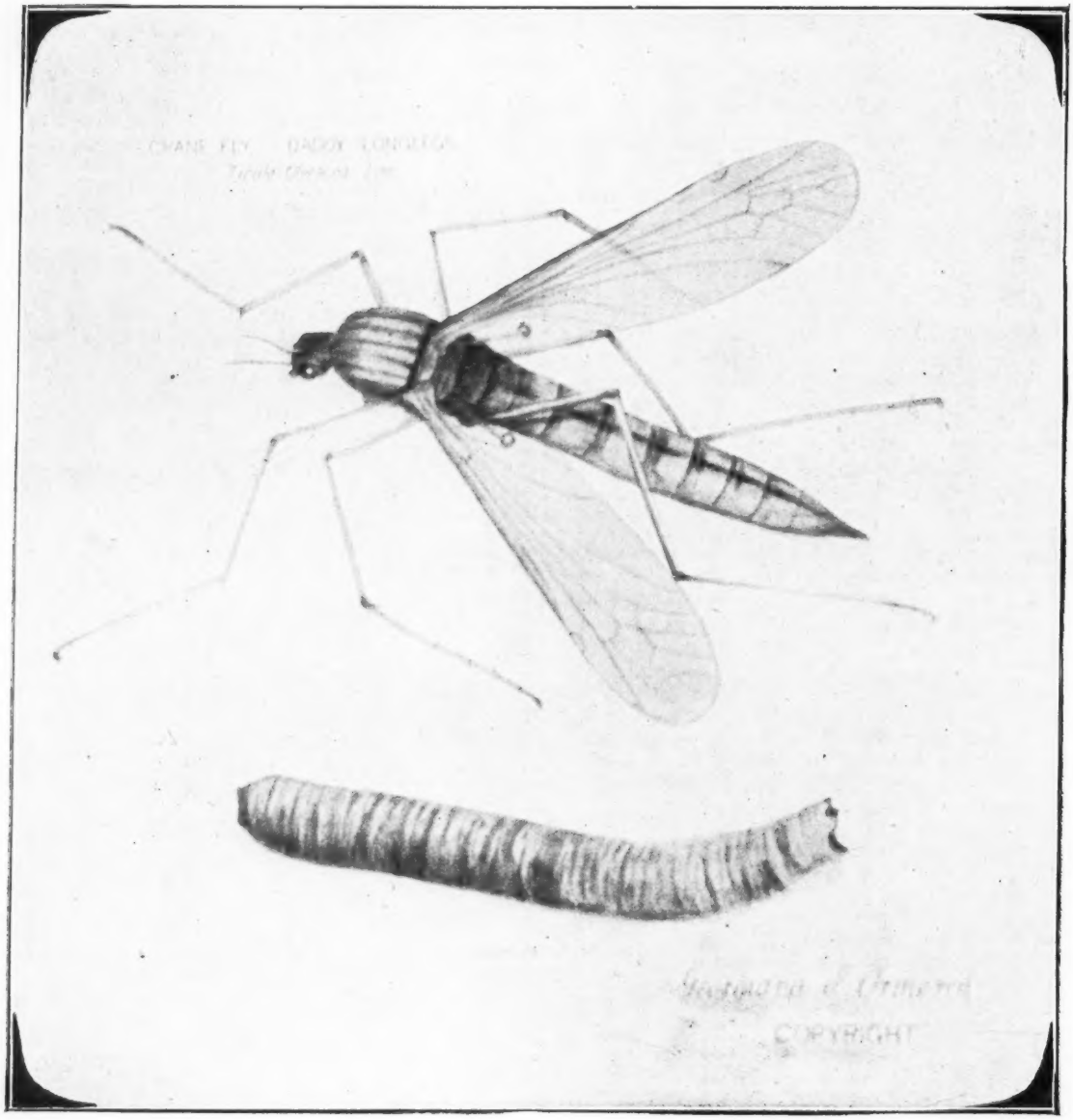
are passed down into the hole. Sometimes, however, they are laid amongst the grass or leafage close to the surface of the ground, instead of being buried. As many as three hundred eggs may be produced altogether by a single female, but they are not all laid in the same spot, and it is difficult to say what determines the number to be included in a single set, unless it be the proportionate abundance of food. The different groups, however, are often laid tolerably close together, and in bad visitations this is necessarily the case. Kirby and Spence record an instance in which the immense number of two hundred and ten grubs were found in a square foot of turf during a terrible plague of them in Holderness in the year 1813.

From the black eggs are hatched thick, greyish, footless grubs, with an extremely tough skin. They are generally known to gardeners as "leather-jackets," or simply as "the grub." They are soft and flexible, but so tough that it is difficult to damage them by any means short of absolutely cutting the body in two or tearing it to pieces. This feature they possess in common with another subterranean grub, which the reader will be careful not to confound with the "leather-jacket," viz., the celebrated wireworm, or grub of skipjack beetles; this creature differs in being thin, hard, inflexible, and of a yellow colour. Though the "leather-jacket's" head is large, it is not generally seen, as it is almost entirely imbedded in the following segment. It is furnished with powerful jaws which are forked at the tip. The entrances to the breathing tubes are reduced to two openings placed at the tail end of the body; here are also some pointed hooks, which, like the head, are usually withdrawn within the adjoining segment when not in use. They are of assistance when the grub works its way through the soil.

This wretched grub is subterranean in habits, and if it does chance to come to the surface, it is only in the night time, or under the shelter of some friendly stone or pile of dead leaves. Its business underground is to devour the roots of plants, and this business it discharges most effectually. It possibly does damage also by loosening the soil round the roots as it works its way about. Its diet certainly seems to suit it well, for it is usually found in a very fat and flourishing condition. Its principal food appears to be the roots of grasses, but it is by no means confined to these. I have found it very destructive to certain garden plants, especially to blue lobelias used as an edging. Shortly after the young seedlings have been bedded out, they begin to look unhealthy and droop and wither. Frequently also the previously erect stems fall into a sloping position and wither away. On removing the soil from the base of the plant to investigate the cause of its drooping condition, a fat "leather-jacket" is found in the centre, just where the rootlets ought to be; the tenderer portions of these have all disappeared, and only the tougher and older parts are left, while many of the stems are seen to be gnawed round or cut completely through at the base, thus explaining their prostrate position and withered appearance. In such cases, unfortunately, one does not discover the enemy till the mischief has been done, and it is too late to save the plant. Of course, such damage is the more likely to occur where the bed is bordered by a grass plot.

This destructive work is carried on by the grubs more or less continuously during the summer months, from May to July, and sometimes they may be found at work even as early as February. During this time, far more than what is actually devoured is caused to perish through the removal of the roots. But it is only fair to remark that some slight plea of defence may be advanced, which will perhaps serve to take the edge off the charge of wholesale destructiveness which must otherwise be made. In eating the roots, the grubs inevitably swallow a good deal of earth, and, in fact, to such an extent is this the case, that so careful an observer as Réaumur thought they lived upon this rather than upon roots; hence they may perform to some slight extent a service similar to that carried out by worms, in the passing of earth through their bodies. Towards the end of summer the grub becomes a chrysalis while still buried in the soil. It now appears as a long, brown, narrow object, which shows indications of the parts of the future fly. The legs are present, but bent up at what will ultimately be their joints, in three parts, which lie parallel to one another on the under side of the head and thorax. The thigh points towards the tail, then the shank is bent back upon this, and finally the tarsus, or foot, points again in the direction of the tail. By this arrangement all the tarsi are made to lie on the outer side and to terminate at about the same level. Of course, these legs, being enclosed within the membranous skin of the pupa, are quite useless for purposes of locomotion.

When the fly is fully formed and ready to make its appearance in the air, the chrysalis works itself up through the soil to the surface by means of certain spines on the abdomen, which point outwards and slightly backwards. Using these somewhat as climbing irons and props, it works its way upwards step by step until all the fore part of the body is above ground. Its legs are now free from the soil, and when drawn out of their sheath, after the splitting of the skin, can be used to assist in extricating the body. But in order to give purchase to the struggling insect in its endeavours to get free from its case, the lower part of the chrysalis remains imbedded in the ground, and the body is withdrawn from the shell, which is left



CRANE FLY OR DADDY-LONGLEGS (*Tipula oleracea Linn.*), **with Grub or Larva.**

From a Picture by Miss Ormerod.

projecting half-way out of the soil (Fig. 4). These empty cases may often be seen at the right season, still standing upright in the holes, as silent witnesses to past resurrections. The newly-extricated fly is at first soft, but soon hardens by exposure to the air, and proceeds to its appointed task—the perpetuation of its kind.

FIG. 4.—Pupa of Daddy-longlegs, with upper part projecting above ground.

The breathing arrangements of the pupa are as peculiar as those of the larva. We have already mentioned that the spiracles of the larva are reduced to a single pair, which are to be found on the last segment of the body. Similarly, the pupa has but two, but these are at the opposite extremity—a very desirable arrangement, as this is the part that is uppermost, and therefore nearest the air, when the insect works its way to the surface. They form two horn-like prominences, which project considerably from the head. Thus, in the daddy-longlegs, the same restriction and reversal of respiratory structure takes place as in the aquatic larva and pupa of the common gnat.

As these insects are so destructive, an important question arises as to the best means of reducing their numbers and checking their ravages. As damp soils, with plenty of loose straggling vegetation, especially grasses, are particularly favourable to their multiplication, it is evident that drainage and the clearance of weeds are two of the most important means of prevention. Untidy, shady corners will often harbour scores of specimens, while on open and cleared spaces in the immediate vicinity they may be sought for in vain. The larger insectivorous birds are certainly of great service in clearing the soil of the "grub"; indeed, according to the belief of Mr. Verrall, the English dipterologist, rooks are by far the best remedy. But perhaps we cannot do better than refer those who are practically interested in the matter to Miss E. A. Ormerod's "Manual of Injurious Insects," where they will find variety enough to make a choice rather embarrassing, since most of the remedies suggested have been found useful on occasion.

But we must caution our readers against putting too much faith in specific remedies, or expecting too much of them, since it is extremely difficult, if not impossible, to obtain an "infallible cure" for insect depredations of any kind. The circumstances of each different visitation, even of the same insect, often vary considerably, and what would be efficacious in one instance might altogether fail in another. Again, just as the satisfactory working of a small model of machinery is by no means always a guarantee that the same thing would work well on a larger scale, so insecticides that may be perfectly efficacious and very rapid in action when administered direct in the laboratory to an individual specimen, may fail altogether when the attempt is made to apply them promiscuously, and on such a scale as would be necessary in a large field, to say nothing of the great expense often involved in attacking such large areas. Of this principle, indeed, Miss Ormerod gives some remarkable illustrations in the book above referred to, appending to them the following pertinent remarks: "The above experiments are of much value by showing how little these remedies can be depended on, some of which have often been tried, and time, valuable for checking the attack at the beginning, thereby lost. It will be observed that the application that caused the most rapid destruction of life experimentally, failed to have any decided effect on the grubs in the ground, even when applied at a strength which, without the greatest care in using, would be destructive to the crop."

Probably natural agencies are, after all, the best to depend upon; but even in this category there are several that might have been thought available, but yet fail through the hardiness of the grub. For example, frost, which kills many insects, has little effect upon the hardy "leather-jacket." They may be frozen hard and stiff, and yet recover on being thawed, and proceed about their business as usual. In some experiments carried out for Miss Ormerod at Kew, specimens were exposed to an artificial cold of −10° F., or forty-two degrees below freezing point, and some were found to resist even this extremely low temperature, though most of them died. Therefore, evidently the frost of an ordinary winter cannot be expected to make much difference to their numbers. Again, it was found that grubs which had remained immersed in water for fifty-eight hours, and looked quite lifeless, recovered on being restored to the air, though an immersion of twice as long proved fatal. Hence floods, to be effectual in killing the grubs, must be of long continuance, and there must be no means of escape to drier quarters. Drought appears, however, to be much more reliable as a destroying agency.

THE CANALS OF MARS.

By E. WALTER MAUNDER, *Hon. Sec. R.A.S., Superintendent of the Physical Department, Royal Observatory, Greenwich.*

SEVENTEEN years ago our knowledge of Mars appeared to be in a very satisfactory state. The principal markings had been often and long observed, and had been found to be permanent. The Kaiser Sea, the Oculus, the Maraldi Sea, had been observed by Hooke and Cassini, Herschel and Schroeter, Beer and Mädler, Dawes, Lockyer, Knobel and Green. The inference, from the annual waxing and waning of the white polar caps, that cloud, snow, and rain were features of the meteorology of the planet, had been confirmed by the testimony of the spectroscope, and that the white caps themselves were composed of ice or snow was a natural conclusion. It followed necessarily that there must be water on the surface of the planet, and the dark spots were considered as seas, leaving the brighter districts to be regarded as land. Mars was, in short, a smaller copy of our own world. "The analogy between Mars and the earth" was pronounced to be "by far the greatest in the whole solar system."

Schiaparelli's discovery of the "canals"—to use a term which, however misleading it has been, has now been too strongly sanctioned by custom to be easily changed—was the beginning of a new epoch in Martian observation, and its chief and most patent result has been to disturb our old conceptions of the analogy between Mars and the earth, and consequently to unsettle our notions of the physical condition of the planet. The reaction has gone so far that Prof. Schaeberle has reversed the old identification of the dark spots as seas, and claimed that the bright districts are to be thus regarded. The grounds for this change of view have not been generally accepted, and more is to be said for an objection raised by Prof. W. H. Pickering, that just as snow is not the only substance to give a bright white reflection—hoar-frost or cloud would serve as well—so water is not the only surface which would appear dark; forests and prairies would appear as at least sombre districts.

The "canals," however, have been the great element of disturbance. The report of their discovery was received in 1877 with very considerable mistrust. But time has

been on the side of the patient and keen-eyed Italian astronomer. Each succeeding opposition has seen more of his "canals" identified by other astronomers; each construction of a new and more powerful telescope, each enlistment of a fresh earnest and skilled observer, has meant a further confirmation of his work. So that now there is a bulk of evidence in favour, not merely of some of Schiaparelli's "canals," but of his canal system as a whole, by no means lightly to be set aside.

The positive evidence has not, however, destroyed or overcome the negative. Both still hold the field, and both must be considered. The principal points against the actual existence of the "canals," as represented by Schiaparelli, may be summarized as follows:—

1. They are extremely narrow objects, approaching the theoretical limits of visibility, even when Mars is at its nearest approach. Thus a fine drawing reproduced in Flammarion's great monograph on "Mars," p. 568, shows "canals" of breadths not exceeding 0·04″ or 0·05″ of arc. The two branches of a *doubled* "canal" in one part of the sketch are distant from each other only 0·25″. Nor is this all. In his account of his 1888 observations (maximum diameter of planet, 15·4″), he states that in a set of canals on Mädler Continent he could make out, not merely the two banks of the canals, but also "very small undulations in their two banks, which could be distinguished from each other."

Fig. 1.—Herschel II. Strait, as seen by Beer and Mädler on October 14th and 19th, 1830. From Flammarion's "Mars," p. 566.

2. The distinctness of some of these objects, though so narrow, does not seem impaired by distance. Thus, in the opposition of 1877, the Indus was *better* seen by its discoverer when the planet had receded a great distance from opposition, and was very well seen when the planet was only 5·7″ in diameter, and the canal 0·2″ in breadth.

3. The great divergency between the descriptions of different observers. To take the one (and all important) feature of breadth. In the opposition of 1890, when Schiaparelli was observing "canals" down to a breadth of 0·05″, Holden and Keeler, at the Lick Observatory, always saw the canals as dark, broad, somewhat diffused bands. We may judge what is meant by "broad bands," for the record goes on:—"In bad vision they were drawn in that way by Schaeberle also. Under good conditions, however, the latter observer described them as narrow lines, a second of arc or so in width." A second of arc corresponded at this time to a minimum of 6° of a Martian great circle; that is to say, to about the breadth of Herschel Strait, and very nearly to that of the Mare Sirenum, the narrower end of the Maraldi Sea, or to nearly double the breadth of the Nasmyth Inlet, or the point of the Kaiser Sea, markings seen even by the earliest observers. If Schaeberle could describe markings of such dimensions—markings twenty times as broad as Schiaparelli's narrowest canals—as "narrow lines," what must have been the breadth of the "broad bands" of his two colleagues? It is clear that the phenomena observed by the Lick observers were quite of a different order to those recorded by Schiaparelli.

4. The greatness and suddenness of the changes remarked in the "canal" system. The "gemination" or doubling of the "canals" has been remarked "to take place in a relatively short space of time, and by a rapid metamorphosis. . . . Sometimes the metamorphosis has been completed in the interval of twenty-four hours between two consecutive observations. So far as the observer could judge, the phenomenon took place simultaneously along the entire length of the canal doubled." Schiaparelli himself draws attention to the strange and rapid changes taking place on the planet, and remarks: "Evidently the planet has fixed geographical details similar to those of the earth, with gulfs, canals, &c., on an irregular plan. There comes a certain moment and all this disappears, to give place to these grotesque polygons and geminations, which clearly represent approximately the former state; but it is a coarse, and, I might say, almost a ridiculous mask."

5. The "canals," when near the edge of the disc, are apt to be represented as much straighter than they could possibly be.

6. To these difficulties may be added that at the very time when to some observers the canal system was most developed, others have sometimes only been able to perceive the usual markings of the planet in their customary configuration.

How are we to explain these curious discrepancies?

First of all, many of these differences are to be explained by differences in "seeing" power, including in that term not merely atmospheric conditions, but instrumental and personal differences, such as the aperture of the telescope, its defining power, the magnification employed, and the keenness of sight and artistic skill of the observer. Two illustrations may be given of these. In 1892 a number of drawings by different observers were made of the De la Rue Ocean. The observers best equipped with instruments, and most favoured by observing conditions, recorded this ocean to be marked by the presence of one, two, three, or more islands. The better the conditions the more the number of islands represented; the smaller the aperture, and the less the experience of the observer, the fewer; so that the drawings showed every variety of representation,

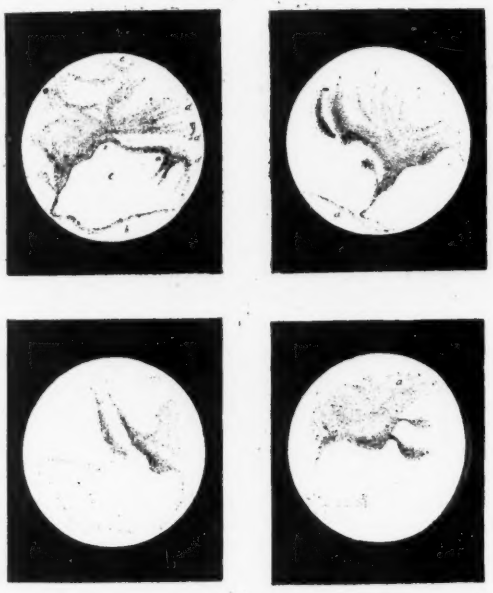


Fig. 2.—Drawings of Mars, by Dawes, in 1864-65. From Flammarion's "Mars," p. 187.

from an undivided greyish spot to an archipelago of five distinct and clearly separated markings.

Again, in Flammarion's "Mars," a series of representations are given of Herschel II. Strait. First in order of date come Beer and Mädler's drawings of 1830, in which we see the "strait" (Fig. 1), not as a strait, but as a snake-like inlet, ending in a dark round spot. In 1862 Lockyer (Flammarion's "Mars," p. 155) represents the terminal spot as a nearly rectangular marking. In the same year Kaiser gives the northern edge of this rectangular spot a shaded appearance, as if he suspected the presence of the two "estuaries" (*Ibid.*, p. 174). In 1864 (first sketch of Fig. 2) Dawes resolves this rectangular spot into the now well-known form of "Dawes' Forked Bay." In 1879 Schiaparelli (Flammarion's "Mars," p. 336) traces two canals flowing into the two arms of the Forked Bay.

These different aspects correspond precisely to the effect of improved "seeing," using that term in the larger sense

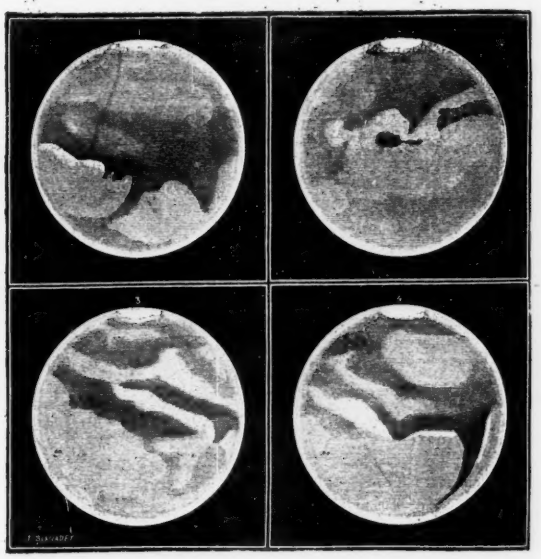


Fig. 3.—Drawings of Mars, by Green, in 1877. From Flammarion's "Mars," p. 274.

adopted above. For if a careful drawing be made of the district under the aspect which it presented to Schiaparelli in 1879, and the drawing be approached from a distance, it will assume in succession precisely the apparent phases delineated by the above-named astronomers; allowance being made for the effect of foreshortening due to the difference of presentation of the planet, and to the inevitable inaccuracies of the drawings of even the most skilful artists.

I ventured to lay stress, in my paper on "The Tenuity of the Sun's Surroundings" in the March number of Knowledge, on the fact, which we so easily overlook, that "the smallest portion of the sun's surface visible by us as a separate entity, even as a mathematical point, is yet really a widely extended area." The same truth applies in its degree to the planet Mars. We have no right to assume, and yet we do habitually assume, that our telescopes reveal to us the ultimate structure of the surface of the planet.

An illustration of this point was afforded me some time ago, when a question arose as to the limit of visibility to the naked eye of sunspots. I was astonished to find that a group of spots had been recorded as seen directly, when their total area was much less than that of many well-defined circular spots that had entirely escaped scrutiny. A few experiments convinced me, however, that the observation was perfectly correct, and that it was often possible to see a straggling group of small unimportant spots, when a single spot of considerably greater total area would be invisible.

I then tried how small an object could be detected without optical assistance, the objects being always black marks (Indian ink) on white glazed paper, illuminated by dull diffused daylight.

The limit of my vision for a circular dot ranged from a diameter of 30″ to 36″ of arc. One of 20″ was quite invisible; of 40″, distinctly seen. This was decidedly smaller than I had anticipated. But the limit for a straight line, to my surprise, was as low as 7″ or 8′; 12″ was easy and conspicuous. More than this, a pair of lines, each only 4″ in breadth, and the pair separated by say 20″, was visible as a faint single line; two lines, even of only 3″, meeting at a very acute angle, were visible after their separation had diminished below about 25″. In each case the object was unmistakably *discerned*, and appeared as a line or dot; it was not, of course, *defined* so as to be seen in its true form.

Further, a chain of dots, each of 20″, irregularly disposed along a straight line, the average interval between any two dots being three times the diameter of a dot, was easily seen as a continuous straight line, whilst a double chain of yet smaller dots, each 4″ in diameter, and the two chains some 40″ apart, was visible as a very faint continuous line.

The theoretical limit of visibility has been given as 40″ or a little greater, a limit with which the above observations are really in tolerable accord; for when the angular diameter of the object fell much below 40″ it was seen, not as a minute defined black dot, but as a grey diffused spot of about 40″ or 45″ in diameter. It would seem, then, that the smallest perceptible area is about 40″, but that if there be within any such given area a sufficiency of dark markings, however individually minute, to turn the white to a decided grey, then that area will be visible as a grey spot. Two lines or a number of dots, easily visible as one object when close together, can readily be made invisible by a greater angular separation.

It seems to me that these rough experiments have a decided bearing upon the "canal system" and the supposed changes of Mars. It seems a violent hypothesis to call in inundations extending over many thousands of square miles to account for merely temporary changes, for sooner or later the old districts take on the old configuration, more especially since, as I have already shown, the meteorology of Mars must necessarily be a languid one. Indeed, it may happen that whilst several independent observers have recorded a change, others equally skilled have seen the planet as before.

But if what we see is not the ultimate structure of the planet's surface, if, especially in the half-tone regions, like the De la Rue Ocean, we have an intermingling of minute areas of dark and light—be they water and land, forest and bare rock, prairie and sandy desert, or what you will—it is easy to see how enormous changes may apparently occur in a very little time. What we actually see is a greyish spot, contrasted with dark spots but little darker than it is, and with bright spots but little brighter. What is required, then, in the observer is not so much keenness of vision to detect minuteness of detail as power to appreciate delicate differences of tone. And the formation or dissipation of thin cirrus cloud above such a half-tone district will

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readily make it indistinguishable from one of the "continents," or from one of the "seas," as the case may be; cloud on Mars necessarily taking the form of our lightest and highest terrestrial clouds, rather than that of the densest and heaviest. When the difference of tone in two contiguous markings is but small, but a little defect in the transparency and steadiness of our own atmosphere will be sufficient to render them indistinguishable.

It is easy to see, if these causes are the principal reasons for the apparent changes on the planet, that different markings will have two or three forms under which they present themselves, but will not pass through an indefinite number of changes. This is actually the case in more than one locality. To take perhaps the best authenticated case, the marking to which reference has already been made, Herschel II. Strait is sometimes closed at its western end, and sometimes open, its southern shore being then a cigar-shaped island. The first sketch in Fig. 3, from Mr. Green's fine series of drawings, made at Madeira, in 1877, illustrates the latter phase; so do also the first, third, sixth, and seventh of M. Guillaume's sketches in Fig. 4. But more frequently the Phillips Island of Green's chart is seen, not as an island, but as an elbow-shaped promontory—the Deucalionis Regio of Schiaparelli.

The rough little experiments to which I have alluded may, I think, throw some light on the "canal system." It must not, of course, be imagined that a power of 100 on Mars when 20″ in diameter will show it with equal distinctness to the moon as seen without telescopic assistance; nor, if a line 8″ in breadth be visible to the naked eye, will a power of 400 show a line 0·02″ in breadth on Mars, even in the steadiest air. To begin with, all the contrasts on Mars are subdued. Then, the gain by increasing the power of the eyepiece is always less than the numerical ratio of the magnification, till a point is reached when it vanishes, either on account of optical limitations, defects of the instrument, or atmospheric conditions. But a narrow dark line *can* be seen when its breadth is far less than the diameter of the smallest visible dot. Further, a line of detached dots will produce the impression of a continuous line, if the dots be too small or too close together for separate vision. There are some intimations that this may be the next phase of the "canal" question, Mr. Gale, of Paddington, New South Wales, having broken up one "canal" into a chain of "lakes" on a night of superb definition, Mars being near the zenith, and Prof. W. H. Pickering, at Arequipa, having under equally favourable circumstances detected a vast number of small "lakes" in the general structure of the "canal system."

If this be so, if the canals are, generally speaking, beyond the limit of distinct definite vision, but producing the impression of lines, it will be readily understood how it is that different observers differ so widely as to their breadth and as to their character, whether diffused or sharp. If they are too narrow to be *definedly* seen, and yet broad and dark enough to make their presence felt, this is precisely what would ensue. The apparent breadth of the "canal" would vary with the definition each observer enjoyed, and with his personal idiosyncrasies. Indeed, one man might see the veritable "canal" itself as a hard, sharp, well-defined line—if that be its actual character—whilst to another, less fortunate in his climate, his telescope, or his sight, it would only be a diffused shade.

That the "canals" are actually very narrow may be inferred from another circumstance. When Dawes discovered his "Forked Bay," he looked particularly to see if he could detect any rivers flowing into these two seeming estuaries, but found none. Now I found that I required to take the distance between the points of the "Fork" on a drawing, not as 8″, but as more than twenty times as much, as fully 3′ of arc in order to see the "bay" as Dawes described it. (This may serve to show how great is the difference between defining an object and merely discerning it.) The actual distance of the points in Martian longitude is 8°. It is practically certain that if the "canals" which flow into the "Fork" had had a breadth

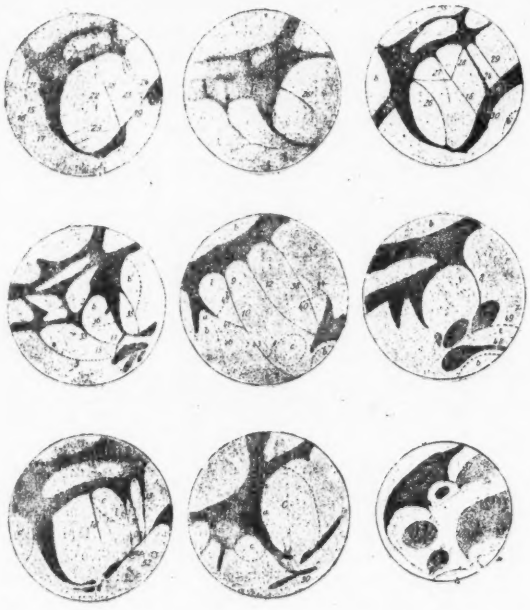


FIG. 4.—Drawings of Mars, by Guillaume, in 1890. From Flammarion's "Mars," p. 477.

of one-sixteenth of that distance, or 0·5° of a Martian great circle, Dawes could not have overlooked them, provided the "canal" was as dark as the "bay." I am inclined to think that the actual breadth of the rank and file of the "canals" cannot exceed this limit, if they are truly continuous lines, and as dark in tint as the "seas." If they are fainter than the "seas," or discontinuous, then they must make up in breadth what they lack in darkness or continuity. Their angular breadth in a favourable opposition would then be about 0·1″, and they would be beyond the limits of *defined* vision, except on the rarest occasions.

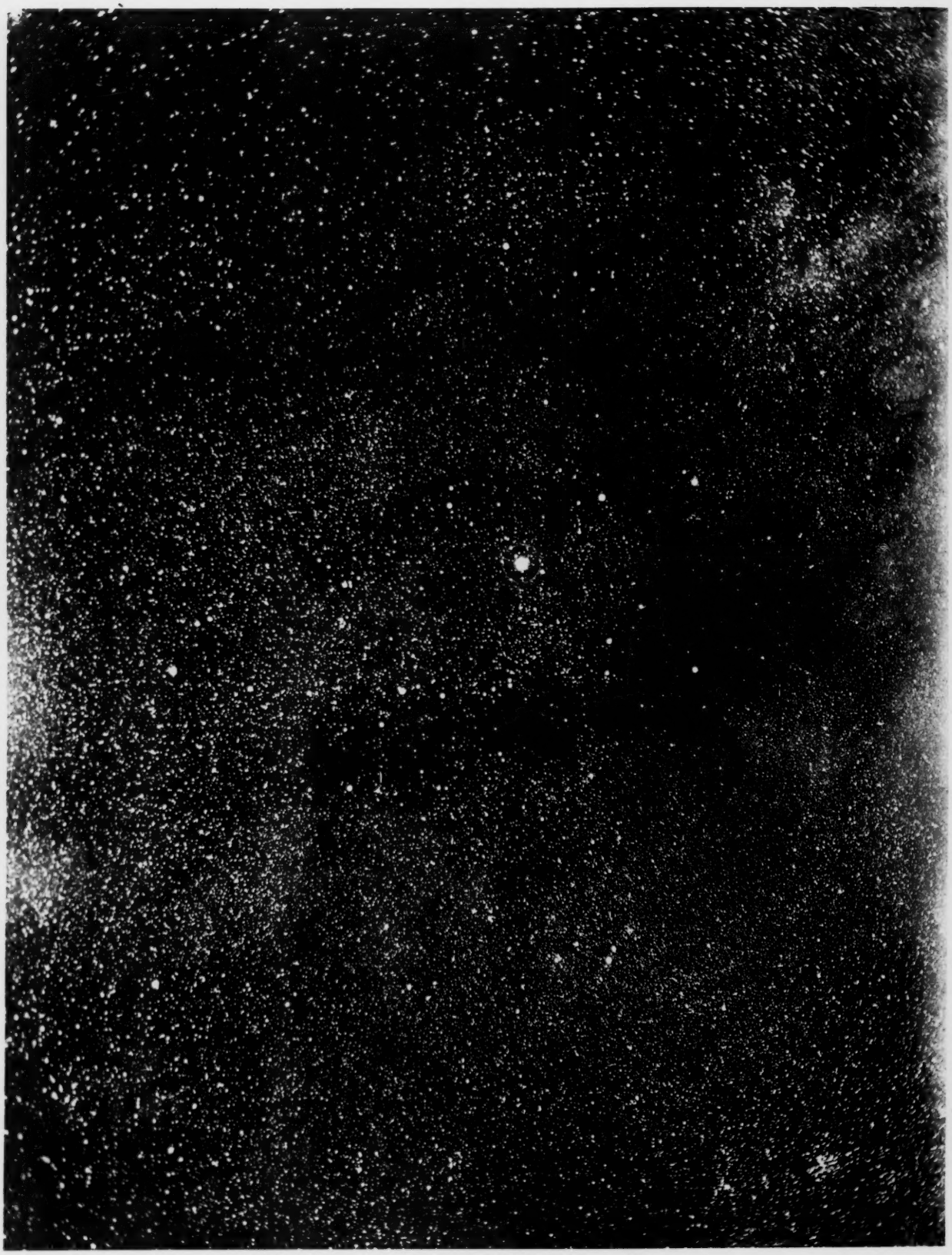
The disappearance, reappearance, and duplication of the "canals" would easily explain themselves. If my theory is correct they are all always present, both the "canals" and their duplicates, but being so close to the limit of vision, a trifling circumstance will bring them within it, or remove them without it. Suppose we take the popular opinion that they are watercourses, then an increase in breadth no greater than our own rivers frequently show, an increase of turbidity, or a greater transparency in the atmosphere above a "canal," will bring one ordinarily invisible into view.

Whether this be so or not, I should like once again to emphasize what I feel to be an important point, not only with regard to the sun and to Mars, but to all the planets. We cannot assume that what we are able to discern is really the ultimate structure of the body we are examining.

XUM

NORTH.

WEST.



EAST.

REGION OF THE MILKY WAY NEAR θ OPHIUCHI.

From a Photograph by Prof. E. E. BARNARD, taken at the Lick Observatory, July 6th, 1894, with an exposure of 3h 35m.

Direct Photo Engraving Company, 9, Barnsbury Park, N.

XUM

EAST.

XUM

STRUCTURE OF THE MILKY WAY.

By Prof. E. E. BARNARD and A. C. RANYARD.

I SEND to KNOWLEDGE a photograph which I have recently made with the 6-inch Willard lens. The picture is in

$$\alpha = 17\text{h. } 15\text{m.}$$
$$\delta = -25°,$$

and was made July 6th, 9h. 30m.—13h. 5m., 1894, Standard Pacific time.

This picture shows the remarkable structure of that portion of the Milky Way near θ Ophiuchi—the large star near the middle of the plate. This is a very obscure region to the naked eye, made especially so by the great clouds to the east and south-east of it. It is essentially a region of vacancies. There is a great chasm here in the Milky Way which sweeps from the east of θ Ophiuchi, under it south, and then westward. Theta itself is in a region of stars and nebulosity. I would, however, question this nebulosity, as it may be only areas of very small stars. There are two peculiar narrow, interrupted vacancies running north and south on each side of θ; the western of these passes quite close to the star. About 2° north of θ is a singular small S-shaped vacancy, which is a very remarkable and striking object.

It will be noticed that in many of these vacancies there are "deeper depths" yet, which almost suggest that the appearance of diffused nebulosity over the region is real nebulosity, and that these dark and black places in it are thin places and actual holes.

This picture, taken in connection with Mr. Wesley's interesting paper in August KNOWLEDGE, will give much food for thought and speculation. I have no doubt Mr. Ranyard will be able to discuss this photograph in his usual thorough style, so I shall leave it with these brief references.

Mount Hamilton, August 20th, 1894.

[The dark vacant areas or channels running north and south, in the neighbourhood of the bright star at the centre of the picture referred to by Prof. Barnard, seem to me to be undoubtedly dark structures, or absorbing masses in space, which cut out the light from a nebulous or stellar region behind them. On the glass positive sent by Prof. Barnard several of such dark areas or dark channels are recognizable in different parts of the photograph. There are three nearly parallel dark channels to the east of θ Ophiuchi, which throw out curving branches on either side, which are well shown in our plate. They appear to me to spring from the great dark chasm or rift which sweeps from the east of θ Ophiuchi to the south, and then under it to the westward. It seems to me that these dark structures most probably spring from the great rift, because the lateral branches all diverge in a direction away from the rift, and there is a resemblance in their spreading heads to the forms which solar prominences assume as the outrushing matter from the sun expands and suffers resistance from the medium into which it is projected. Several smaller dark channels may be traced diverging from different parts of the great rift; one from near its western end stretches downwards into a very complicated head, with diverging narrow branches.

It is comparatively easy to conceive of a narrow stream of dark nebulosity or foggy matter cutting out the light of a uniform background; while if the narrow dark regions correspond to thin places or holes in the nebulosity, they must be holes or thin places extending in a direction away from the earth. The probabilities against such a radial arrangement with respect to the earth's place in space seem to my mind to conclusively prove that the narrow dark spaces are due to streams of absorbing matter, rather than to holes or thin regions in bright nebulosity. — A. C. RANYARD.]

Science Notes.

Mr. Richard Inwards delivered an interesting presidential address to the Meteorological Society on "Some Phenomena of the Upper Air." He described the experimental balloons which have been sent up in France by M. Hermite, carrying instruments so contrived as to register the various changes of condition through which the balloon passes. The results are most instructive. It appears that one of these balloons rose to a height of ten miles, when the pressure of the air was only 4·1 inches of mercury and the temperature — 104° F. Though there are considerable variations in the temperature gradient below twelve thousand feet above the sea level, it seems that above that height the temperature decreases pretty regularly, falling one degree for every rise of three hundred and thirty feet into the air.

Our cup of tea hitherto has come to us as an unquestionable oriental, a thing unique in the flavour of the far East that it brings with it. But soon, it seems, all that will be changed, for America has discovered that she can grow tea as good if not better than that of India or China. Through private enterprise, aided by the Government, tea, reported by experts to be of very fine quality, has been most successfully grown at Pinehurst, near Charleston, U.S.A., and there seems to be no reason why its cultivation should not quickly become general in many districts.

In the chemistry section of the British Association, Prof. H. B. Dixon, in his opening address, gave an entertaining historical account of Oxford chemistry. After Boyle left in 1668, the impulse he had given to its study gradually died out. In 1683 we are informed that "the Oxford elaboratory was quite finished." In 1708 Richard Frewin is described as being Professor of Chemistry there. Uffenbach, after a visit to Oxford about that time, says he found the stoves in fair condition, but everything else in the "elaboratory" was in dirt and disorder. Frewin must have been a man of great facility, for in 1727 he was elected Camden Professor of Ancient History. Whether he still looked after the elaboratory, or whether it went professorless, is not stated. At all events, Frewin must have been a conscientious man in his way, in spite of that suggestive fact about the stoves, for on his election to the chair of History he seems to have made a genuine attempt to become familiar with the new subject, and we are told that he at once expended one hundred pounds in books on chronology and history to fit himself for his duties. The occupation of the chair of Chemistry seems in those days to have been mere by-play in the career of a man. Richard Watson, who ultimately became Bishop of Llandaff, was in 1764 appointed Professor of Chemistry at Cambridge. We are told that he knew nothing at all of chemistry; he had never read a syllable nor seen an experiment. So on his election he sent in a hurry to Paris for an "operator," and set to work in his laboratory. Clearly in those days there could not have been quite so much to learn as now, for fourteen months after we find him lecturing to a large audience.

XUM

The Physical Society is about to follow the example of the Chemical Society, and in January next will commence to publish a monthly pamphlet of abstracts of papers appearing in the principal foreign journals devoted to physics. There is an urgent need for a publication of this kind in each department of experimental science.

Prof. Burnham writes:—"A few weeks ago Messrs. Clark tried the new Yerkes 40-inch objective on stars for the first time. The result was very satisfactory. Alvan Clark thinks that this will be, when finished, the best large objective ever made. I hope to get off to New England in a week or two, and if the weather is good I shall have a chance to look through it."

Notices of Books.

The Rise and Development of Organic Chemistry. By Carl Schorlemmer, LL.D., F.R.S. Revised edition by Arthur Smithells, B.Sc. (Macmillan and Co., 1894.) This valuable book has long been out of print, though French and German translations of it have appeared in 1885 and 1889. Shortly before Prof. Schorlemmer's death he commenced to make corrections and additions for a new English edition, sending the manuscript to his old friend and pupil, Prof. Smithells, for correction in English. The book was not proceeded with very far when Prof. Schorlemmer died, and Prof. Smithells has since, at the request of the executors, completed it, and has added a most appreciative biographical notice of his friend. Carl Schorlemmer was born at Darmstadt in 1834. He commenced his working life in an apothecary's shop; his schoolfellow, Dittmar, had become assistant to Bunsen at Heidelberg, and, inspired by contact with Bunsen, Schorlemmer soon decided to give up pharmacy and devote his life to scientific chemistry. In 1859 he became assistant to Prof. Roscoe at Owens College, Manchester, and was soon, at Prof. Roscoe's request, appointed to a separate chair of Organic Chemistry.

We have received the following books, &c., for notice:—

Ponds and Rock Pools: with Hints on Collecting for and the Management of the Micro-Aquarium. By Henry Scherren. (Religious Tract Society.)

The Complete Poetical Works of Constance Naelen. (Bickers & Son.)

Popular Astronomy. By Camille Flammarion, translated from the French by J. Ellard Gore, F.R.A.S., &c. (Chatto & Windus.)

A Laboratory Manual of Physics and Applied Electricity. By Ed. L. Nichols. Vol. II., Senior Course. (Macmillan & Co.)

Edible and Poisonous Mushrooms. By M. C. Cooke, M.A., LL.D. (S. P. C. K.)

Our Secret Friends and Foes (Micro-Organisms). By P. F. Frankland, Ph.D., B.Sc., F.R.S. (S. P. C. K.)

Fruit Culture for Profit. By C. B. Whitehead, B.A. (S. P. C. K.)

Text Book of the Diseases of Trees. By Prof. R. Hartig. English translation. (Macmillan & Co.)

Manual of Physico-Chemical Measurements. By W. Ostwald. English translation. (Macmillan & Co.)

From the Greeks to Darwin: an Outline on the Development of the Evolution Idea. By Henry F. Osborn, D.Sc. (Macmillan & Co.)

The Slide Rule: a Practical Manual. By Chas. N. Pickworth. (Emmott & Co., Limited.)

Photo-Micrography. By Dr. Henri Van Heurck, translated by W. E. Baxter, F.R.M.S., F.G.S. (Crosby Lockwood & Son.)

Fallen Angels; a Disquisition upon Human Existence. By One of them. (Gay & Bird.)

From Spring to Fall: or when Life Stirs. By a Son of the Marshes. (Blackwood.)

Amphioxus and the Ancestry of the Vertebrates. By Arthur Willey, B.Sc. (Macmillan & Co.)

Report on Meteorological Observations in British East Africa, for 1893. By E. G. Ravenstein, F.R.Met.Soc. (Geo. Philip & Son.)

Practical Physiology of Plants. By Francis Darwin, M.A., F.R.S., and E. Hamilton Acton, M.A. (Cambridge University Press, 1894.)

The Royal Natural History. Part 12. (F. Warne & Co.)

Science for All. Part 57. (Cassell & Co.)

The Universal Atlas. Part 1. (Cassell & Co.)

Index to World's Technical and Scientific Literature. Sections I., II., and III. (Romeike & Curtice.)

Letters.

[The Editor does not hold himself responsible for the opinions or statements of correspondents.]

To the Editor of KNOWLEDGE.

DEAR SIR,—The article by Mr. Evershed in your October number recalls some questions that I tried to answer, and some experiments made by me some twenty years ago, and which, I think, tend to confirm his conclusions.

It seemed to me that in the production of light for illuminating purposes, we were, as a Chinaman would say, "burning our house down to roast the pig." In fact, we were using a large quantity of energy in heating up bodies so as to become luminous, and getting a very small amount of that energy utilized in the production of light. It occurred to me that if it were possible to set up in the molecules of the body used vibrations of a high light-giving order only, none or only a small portion of the energy would be wasted in heat radiation.

The method of electrical excitation in tolerably high vacua seemed the most promising one to follow, and I estimated the quantity of heat produced in gases in various tubes under various conditions of vacuum and current.

For my present purpose I need only say that the heat simultaneously given off was large, and I had not produced light vibration alone by any means.

On consideration of the experiments, I could see no difference in the light and heat-giving effects between the gas electrically luminous, and what one would expect to find if the same were rendered luminous by heating in the ordinary way. I concluded that whether a gas be excited electrically, or chemically, or by ordinary heating, its vibration is of the same kind, or at least there is nothing pointing to the contrary, and my expectations had been misled by the fact that gases under electrical excitation are usually very rare, whereas when ordinarily heated they are at atmospheric pressure, or thereabouts.

The exact manner in which heat, chemical, and electric excitations act on the molecules of a gas is unknown; but is there anything to show that the result of the action of one on a gas is different in kind to that of another? I expect not. I picture to myself the molecule of a gas, at ordinary temperatures, rapidly changing its shape to a small extent, in the manner of a soap-bubble just released from a pipe; under greater excitation, at higher temperatures, I imagine waves running over its surface, and under still greater excitation, ripples on these waves. It is these waves and ripples that produce heat and light through the medium of the ether—certain waves and ripples, fitting the size and elasticity of the molecule, being

predominant, hence definite lines in the spectrum of each kind of molecule. I further picture these molecules flying about and colliding. The greater the vibration of the molecules, the higher the velocity in their respective paths; and the greater the velocity, the greater the collisions and consequent vibration. Thus give your molecules an impulse of vibration, or of translation, and the result in a short time is the same.

I can confirm Mr. Evershed's experiment with iodine vapour, in part at least, although I performed the experiment from another point of view. I imagined that if an absorbing vapour were viewed from the side, a spectrum, complementary to that seen by transmission, should appear. To this end, I enclosed iodine in a small cage of wire gauze with apertures at right angles to each other. I passed the rays from a lime-light through in one direction, focussing the image of the lime in the cage so as to get the most intense illumination, and viewed the transmitted light. The iodine was then vaporized by a flame below and the usual absorption spectrum viewed, and simultaneously the vapour was examined by a spectroscope pointed at right angles to the former. I saw no complementary spectrum, but only a very faint general illumination, too faint to call a continuous spectrum. The temperature was, however, low. I put my failure to see a complementary spectrum down to the probable fact that the vibrations set up by absorption, already faint, would be communicated to molecules outside those immediately absorbing from the lime-light on their way to the eye, and so the vibrations would be frittered down to too small an extent to be visible.

The faint general illumination seen by me, and the continuous spectrum seen by Mr. Evershed, were probably due to the closeness of the molecules, which in such case have not sufficient time between collisions to settle down into their natural periodic vibrations, as in the case of a solid or liquid. Many years ago, Prof. Lockyer showed the widening of the lines of hydrogen by increase of pressure, and Mr. Evershed's experiment with sodium vapour points to this explanation.

Owing to the large number of different periods in which the iodine molecule can vibrate, as evidenced by its absorption spectrum, it would appear probable that a less density of the vapour under examination would be necessary in order to give its specific spectrum than in the case of sodium, with its more simple vibrations.

Yours truly,

Rugby. G. M. SEABROKE.

[Mr. Seabroke's experiments on the radiation from vacuum tubes electrically excited appear to show, as he says, that there is no essential difference in the radiation of a gas, whether it is produced electrically or otherwise. It is probably entirely a question of temperature, or, for any given substance, molecular velocity, and it appears to me that all ordinary cases of gaseous radiation can be explained in this way without resorting to the hypothetical phenomenon called "luminescence." Thus Prof. Smithells has shown that, in the case of flames tinted with metallic salts, where the radiation exceeds that of a perfectly black body raised to the average temperature of the flame (for the rays special to the metal or salt), this so-called "luminescence" of the salt may be really due to the fact that the *average* temperature is very much lower than the temperature of such molecules in the flame as are in the act of combining; and that the intense radiation, therefore, may after all be merely a heat effect, the extremely high temperature of the combining molecules being communicated to a certain proportion of the salt molecules. With regard to the iodine radiation, I do not think it is simply a question of molecular aggregation acting in the way Mr. Seabroke supposes. I have observed the iodine emission spectrum under a variety of conditions as to density, but in no case can I get any indication of a discontinuous emission, and think that this can only be obtained with higher temperatures than I have hitherto employed.—J. EVERSHED.]

GLOBULAR STAR CLUSTERS.

To the Editor of KNOWLEDGE.

DEAR SIR,—With reference to your remarks on my paper in the October number of KNOWLEDGE, in which you say that my views carry us "back to the old theory, that clusters and nebulæ are distant galaxies, outside and unconnected with the Milky Way," I would like to say that I do not believe that the clusters and nebulæ are external galaxies. On the contrary, I say in my paper, "Judging, however, from the average distance recently found for stars of the first and second magnitudes, the distance of ordinary stars of the fourteenth magnitude—on the supposition that they are of the same size and brightness, and that their light is simply reduced by distance—would be about ten times greater than that found above for Omega Centauri." This, I think, clearly implies that I consider the globular clusters to be included within the limits of our sidereal system. If any external universes exist, which seems probable, I do not think that any of them are within the range of our largest telescopes. These views I have already expressed in my "Visible Universe."

That some of the brighter stars may be many times larger than the sun I admit, but that bodies of the size of the earth should retain for ages their solar brilliancy seems to me very improbable. Some of the fainter stars in the Pleiades may lie far beyond the cluster itself.

Yours faithfully,

J. E. GORE.

[The way in which star clusters are distributed in the heavens along the stream of the Milky Way, shows that star clusters are intimately associated with the Milky Way, and that they are at about the same distance from us as the nebulous stream. Herschel's "flat grindstone theory" of the structure of the Milky Way has, I think, now been very generally abandoned by modern astronomers, and the generally received idea is that the Milky Way stream has probably a roughly circular section, so that the most distant stars in the stream are probably not fifty per cent. more distant from us than the nearer stars in the stream.

If one part of the nebulous stream which encircles the heavens were ten times as far removed from us as another, we should expect to find the more distant part appearing narrower or fainter by reason of its distance; but there is no very great difference in the general breadth or brightness of different parts of the Milky Way stream. It seems therefore probable that the nebulous ring is not very far from circular, and that the earth is not very far removed from the centre of the ring; that is, one part of the stream is probably not two or three times as far removed from us as another. We cannot, therefore, assume that star clusters which are closely associated with the nebulous stream, or are distributed along its borders, are some of them ten times as distant from us as others.

Mr. Gore's reasoning with regard to the smallest conceivable size of luminous star depends upon the assumption "that they retain for ages their solar brilliancy"; but man has only observed them for a few years, and we have no evidence that they are not rapidly cooling and were not raised to incandescence by a comparatively recent collision. —A. C. RANYARD.]

HOW NOXIOUS GASES AND VAPOURS FROM ALKALI AND OTHER WORKS ARE UTILIZED.

By GEORGE MCGOWAN, Ph.D.

BLUE-BOOKS and reports generally are not always considered light and fascinating reading, but anyone who is interested in the progress of manufacturing chemistry will find much to repay him in a perusal of the "Report on Alkali, etc., Works" for last year (the thirtieth annual report), which was presented in the spring to the Local Government Board and to the Secretary for Scotland by the Chief Inspector, Mr. A. E. Fletcher. The heading "Alkali, etc., Works" comprises not merely alkali works proper, and works for the preparation of sulphuric and other common acids, but also those for tar distillation and for the manufacture of cement, sulphate of ammonia, chemical manures, Venetian red, barium compounds, lead deposit, white arsenic, nitrate and chloride of iron, felt, zinc, etc. As a matter of fact, only a small minority of the works on the register are alkali works. It would, of course, be quite impossible to give within the limits of this article anything like a detailed account of the important work in which Mr. Fletcher and the other inspectors who are associated with him are engaged, but a few of the salient points in his report may be referred to with advantage.

To begin with, there are now no less than 1046 works of the above kind registered in England, Ireland and Wales, and 127 in Scotland; and in these 1703 distinct processes of manufacture are carried on which come under the Act of 1892 (*i.e.*, 1495 in England, Ireland, and Wales, and 208 in Scotland). In the course of last year 5332 visits were made to the various works by the inspectors, and 4974 tests were carried out. "The tests above referred to are the results of exact chemical determinations made of the amount of acid gas or other matter in a measured volume of the escaping air, taken either from the main culvert or, more usually, from the chimney itself. The analysis is either made on the spot by the help of portable apparatus arranged for the purpose, or the collected material is taken home for examination." The public generally will be glad to hear that "the amount of noxious gas (escaping), though now much below that of the legal standards originally imposed, still gradually diminishes year by year."

Take first the case of hydrochloric or muriatic acid, which is evolved in such enormous quantity in the manufacture of soda by the old or *Leblanc* method, and the escape of which, before the Alkali Acts came into operation, made the country into a desert for miles round an alkali work. By the Act it is obligatory to condense 95 per cent. of the hydrochloric acid generated—*i.e.*, the manufacturer may legally allow 5 per cent. of it to escape. But, taking the average of all such works, only 1·72 per cent. escapes in England, Ireland and Wales, and 3·32 per cent. in Scotland. This condensation has been found in the end to be greatly to the advantage of the manufacturer, from the value of the hydrochloric acid thus saved. To diverge for a moment from the subject in hand, this seems to supply an argument in favour of compulsory coal smoke consumption in works generally. The consumption of coal smoke is, of course, a much more difficult problem than the condensation of hydrochloric acid, and trade is at present not in a condition to bear unnecessary restriction or legislation; but even allowing for all this, the question is one which well deserves the practical attention of all who are interested in sanitation, affecting as it does the whole urban community more or less directly.

To return to Mr. Fletcher's report. In the two well-known methods of alkali manufacture, the newer ammonia-soda process has almost outstripped the older *Leblanc* process, so far as the production of the main article, soda, is concerned. But, as hydrochloric acid and bleaching powder are bye-products of the *Leblanc* method, while they are not obtained at all by the other, the former has maintained its ground by their help. Some seven years ago, as has already been described in KNOWLEDGE, a most ingenious scheme was worked out by Mr. Chance, of Oldbury, near Birmingham, for the recovery of sulphur from alkali waste, immense heaps of which used to be accumulated round alkali works (there being one and a half to two tons of waste for every ton of soda produced by the *Leblanc* method). This "waste" has constituted in many cases a standing nuisance, from the fact that it gradually undergoes decomposition by the atmosphere, and more quickly by the acid vapours still found to some extent in the neighbourhood of chemical works, the result being that it evolves that nauseous and poisonous gas, sulphuretted hydrogen. During the last few years many improvements have been made in this (now spoken of as the *Chance-Claus*) process. When it is mentioned that more than 5,000,000 cubic feet of mixed air and sulphuretted hydrogen (the latter being obtained from the "waste" by the above-mentioned method) are dealt with in this way every twenty-four hours at one of the larger English alkali works, when in full operation, some idea may be formed of the care required to keep the numerous stopcocks, pipes, and vessels tight—a task which is now satisfactorily accomplished. "The application of the process is now so far advanced that already apparatus for treating the whole of the tank waste of St. Helens and Widnes has been constructed. Most of that produced on the Tyne is also so treated, as is that at Oldbury and Wednesbury." About 35,000 tons of sulphur are now recovered in this way per annum. This constitutes a veritable triumph in manufacturing chemistry. And the process is susceptible of yet further improvement, as about 15 per cent. of the sulphur contained in the "waste" under treatment is still lost in the exit gases. None of it, however, is allowed to escape into the atmosphere as sulphuretted hydrogen, those exit gases being mixed with air and then passed through a fire, with the result that all the sulphuretted hydrogen present is converted into the much less harmful sulphurous acid; and this latter is to some extent utilized in making sulphuric acid.

The sulphate of ammonia produced in Great Britain and Ireland amounted in 1893 to 152,762 tons (worth more than £2,000,000 sterling), an increase of almost 3000 tons over 1892. Three-fourths of this was got from the ammonia liquor of the gas works, the remainder being from shale, iron, coke and carbonizing works. The manufacture of this salt, which is of such supreme importance for agriculture, used to be most offensive, from the copious escape of sulphuretted hydrogen and other noxious gases. Mr. Fletcher now writes with regard to it:—"It is a matter of great satisfaction to be able to report that no complaint has been brought during the past year against any of these works," so much improved are the methods of treatment.

The arsenic works of Cornwall and Devonshire, where white arsenic is prepared in large quantity by roasting arsenical pyrites, were formerly the cause of frequent litigation. This arose from the alleged destruction of cattle through eating grass said to have been poisoned by arsenic which had escaped condensation in the long flues used for the purpose (extending in one case to over half a mile in length). After ineffectual attempts had been made

to obviate this evil by means of wash-towers, a *dry* filter made of brushwood, gorse, etc., was suggested, and this has been found to arrest almost the whole of the arsenic fumes in the escaping gases. In one case, where there was no such filter, a test of the chimney gases showed the presence of as much as 7·4 grains of arsenic in a cubic foot of the gases passing into the air, whereas, with dry filters of the kind, the average is now less than one-tenth of a grain per cubic foot.

The above remarks refer to but a few of the points, taken almost at random, in this most interesting report. Its author (or rather authors, for Mr. Fletcher's contribution is supplemented by other reports from the inspectors for the different districts) would be the last to claim that the work had by any means approached perfection. But the short sketch just given will enable the readers of KNOWLEDGE to appreciate the fact that an immense deal has already been done in the way of preventing the escape of noxious gases and vapours into the atmosphere, with a corresponding benefit to the health of the community and a large saving of valuable material. The climate of our country is too damp to allow of the air here being as clear as that of more southerly and drier regions ; but we may at least look forward to the time when increased knowledge, and its judicious application, will bring about such an improvement in the air breathed by the people of our towns and manufacturing districts as to make life in these both pleasanter and healthier.

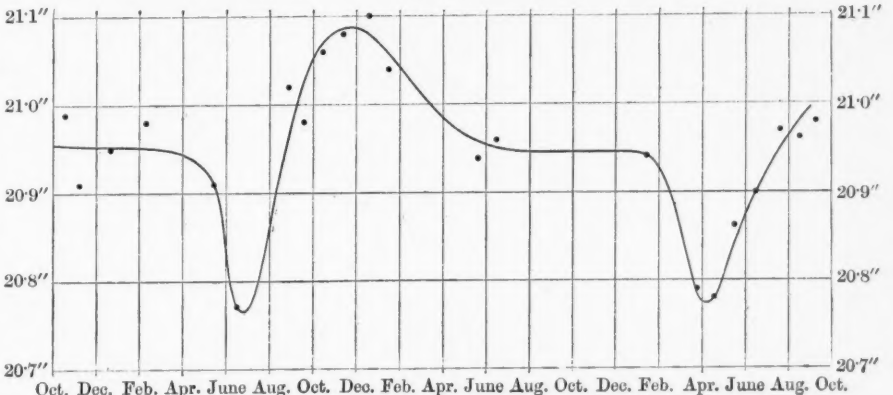
A CLASSIC DOUBLE STAR.

By MISS A. M. CLERKE, *Authoress of "The System of the Stars" and "A Popular History of Astronomy during the Nineteenth Century," &c., &c.*

NOT far from seventy years ago, Friedrich Struve declared that the mathematical probability of a physical connection between the stars of 61 Cygni was actually greater than that of the sun rising the morrow morn. Yet these "odds beyond arithmetic" possibly misled him. It cannot, indeed, for a moment be supposed that the luminaries are of independent origin, or have had independent histories. Their common proper motion—the largest belonging to any known compound object—of itself establishes a close tie between them ; it has, moreover, been learnt, since Struve wrote about them in 1827, that their apparent vicinity is real, their parallaxes being sensibly the same; finally, they are both yellow stars showing a spectrum of the second type. Their photometric magnitudes are 5·5 and 6·3.

Our records of them go back to 1753, when Bradley noted their separate transits; and an ample store of accurate determinations of their distances and position-angles has been collected since 1825. Yet no certainty has yet been obtained that they form a true binary system. They possess, as a matter of course, a certain amount of relative motion, otherwise nothing could prevent their falling together; it shows, however, no sign of the anticipated orbital character. The stars apparently travel along right lines, inclined to each other at an angle of about two degrees, the smaller with a velocity slightly inferior to that of the larger. The inference that they were separating never to be reunited was arrived at by Captain Jacob as early as 1858 ; and a fresh discussion, after sixteen further years of observation, led M. Flammarion to the same conclusion. Nevertheless, orbits for the pair, based no doubt in part upon illusory observations, were calculated in 1883 by Mr. Mann, of Rochester, New York, and in 1885 by the late Dr. C. F. W. Peters; but neither of them claims any longer a shadow of authority. At the same time, Prof. Hall's opinion, founded upon determinations made by him at Washington during the years 1879 to 1881, is slightly in favour of the star's binary nature; and an attempt to fix the centre of gravity of the system gave 3·4 to 1 as the proportion of the masses of its components. But no indications whatever of a definite orbit could be traced. Mr. Burnham, on the other hand, has no doubt that the march of both stars is absolutely rectilinear ; that they are separating, and will continue to separate ; and that the evidence of their present conjunction must, in the distant future, become wholly obliterated. If this be so, they were formerly much closer together than they now are, and each must, in all probability, have executed a hyperbolic sweep round their common centre of gravity. This little adventure might not be inconsistent with the state of things sketched out by Prof. Newcomb, since we are acquainted with comets which—without finally renouncing their allegiance to the sun—have described hyperbolas round Jupiter. Not that the two cases bear detailed comparison; but their likeness, though elementary, is instructive.

"The only conclusion open to us," remarked the last-named authority in connection with Mr. Burnham's verdict regarding the status of these stars, "is that each of them describes an immense orbit, which may be several degrees in apparent diameter, and in which the time of revolution is counted by thousands of years." An enormous mass would, however, be needed in order to control the velocity of 61 Cygni. For here an important distinction comes in. Only the small *relative* motion of its components has to do with determining the nature of their association ; but the swift movement which they share must be accounted for in any attempt to divine the organization of a grand system including them as co-equal members. Their high rate of



Wilsing: Changes in Distance of the Components of 61 Cygni.

speed constitutes in itself a formidable problem. That part of it alone which lies across the line of sight amounts to thirty-five miles a second, or nearly twice that of the earth in its orbit. This, according to Prof. Newcomb, is beyond what can be swayed into a closed path by the gravitative force of the entire sidereal system; in other words, 61 Cygni must be reckoned a "runaway pair." Unless, indeed, a single mass comparatively close at hand be effective where the innumerable scattered bodies of stellar space are impotent. It may be worth while to take a glance at the conditions involved in this hypothesis.

Assuming 61 Cygni to revolve round a local centre in a period of ten thousand years, it follows, from the elementary principles of celestial mechanics, that the radius of its orbit, supposed to be circular, would be about 1752 thousands of millions of miles, while the mass occupying the centre would exceed that of our sun two and a third million times. The presence, however, of such an immense gravitative power, even if lodged in an obscure body, would assuredly betray itself otherwise than by the proper motion of one luminous couple. The sphere of its pre-eminent influence might well be twenty billions of miles in diameter, within which incomprehensibly vast region tides of movement should be raised, neither inconspicuous nor difficult of interpretation. But no such effects are traceable. The inference is irresistible that no obscure centre of overwhelming power exists in that neighbourhood; consequently, that the motions of 61 Cygni must be otherwise accounted for.

Now, however, a further complexity has been added to this already complex problem.

In the middle of 1889, as the upshot of a keen scrutiny with powers up to 1000 on the Lick thirty-six inch, Mr. Burnham recorded both the stars of 61 Cygni to be undoubtedly single. It is unlikely that they will ever appear otherwise. Nevertheless, one at least of them owns an attendant by no means insignificant in mass. That is to say, the evidence of this being the case is very strong; it would be premature to assert it to be conclusive.

The thirteen-inch International photographic refractor of Potsdam was placed by Dr. Vogel, in the autumn of 1890, at the disposal of Dr. Wilsing for the purpose of some experimental researches into stellar parallax; and, almost as a matter of course, their chosen object was 61 Cygni. Yet, the proved accuracy of the measures notwithstanding, only anomalous results were obtained. Now an anomaly often gives the clue to a discovery, and Dr. Wilsing soon found himself on the track of a curiously interesting one. His measurements were executed from the middle point of the line joining the stars under examination to two comparison stars, one situated nearly in the prolongation of the same line, the other at right angles to it. The parallaxes derived from both ought, of course, within certain narrow limits of error, to have been the same; yet they differed consistently and notably. After other tests had been applied in vain, direct determinations were carried out of the distances separating 61_1 from 61_2 Cygni at various successive intervals of time. And here at last the secret of the observed perplexing inconsistencies was found to lurk. The stars, it seems, alternately approach and recede from each other, in a period of twenty-two months, by the total angular amount of three-tenths of a second—a gross quantity in an investigation of so delicate a character. The fashion of this change, so far as it has yet been made known, is shown in the accompanying drawing by Dr. Wilsing. It will be observed that the swing backwards of the stars is much more quickly performed than their swing forwards, and this obviously through no accidental errors of measurement, but as a distinctive feature of the systemic movements unexpectedly betrayed. These, as Dr. Wilsing pointed out on the 26th of October, 1893,* must be due to the presence of one or more obscure companions to the bright stars. In due time we shall doubtless learn which suffers disturbance, or whether both alike are composed of a shining and an obscure body. In the latter case, the argument in favour of their permanent physical union will be strengthened beyond contravention.

The spectrograph will afford the surest criterion of the genuineness of Dr. Wilsing's discovery. Up to this, nothing has been ascertained regarding the motions of 61 Cygni in the line of sight. Its rays are too scanty, unless concentrated by a very powerful telescope, to afford satisfactory information on the point. None of the Potsdam instruments are adequate to the purpose; but with the Pulkowa thirty-inch, perfectly definite results ought to be attainable. A complete set of spectral photographs of both stars, with iron-lines for comparison simultaneously imprinted on the plates, seems a primary requisite for the pursuit of this important inquiry. The line-shiftings legible on them would possess a particular significance. It is, indeed, probable that the multiplicity of 61 Cygni might have been detected by the spectroscope alone. For the plane of the minor orbits traversed by some of its components appears to lie along the line of sight from the earth; and twice in every revolution, accordingly, nearly the whole of their velocity in those orbits—amounting probably to six or eight miles a second—must be directed towards or away from the earth. It is thus permissible to hope that many of the intricate questions relating to our classic double star are on the eve of receiving definitive replies.

THE KONISCOPE.

By Dr. J. G. McPherson, F.R.S.E., *Lecturer on Meteorology in the University of St. Andrews.*

Mr. JOHN AITKEN, F.R.S., has just given us the results of some careful observations on colour phenomena connected with cloudy condensation, and an account of his new instrument, for detecting the impure state of the air in rooms by means of colour alone, may be interesting to readers of Knowledge. No more painstaking or persevering physicist lives than the discoverer of the now acknowledged theory of the formation of dew. He has elucidated the formation of fog particles by the attraction of dust for water vapour, and has enumerated the particles of dust in a cubic inch of air, and this is another example of his assiduity and success.

If steam be blown into the air inside a glass vessel, the cloudy condensation will in time undergo a change. Of course, the dust particles in the air have seized hold of the water vapour of the steam to form visible steam particles, each dust atom forming a free surface for the adherence of the moisture. Particles fall and leave the upper part clearer, and particles fall to the bottom also. Yet the principal cause of the thinning change is in the smaller particles becoming absorbed by the larger ones. The smaller drops begin to lose their accumulated moisture, while the larger ones are still increasing in size, growing at the expense of the gradually diminishing smaller ones. In the end a comparatively small number of drops have absorbed the moisture which was previously distributed

* *Sitzungsberichte der Berliner Akademie der Wissenschaften*, xl., 879.

over a vast number of particles. The larger particles have devoured the smaller, and inanimate cloud particles have been struggling for "the survival of the fittest."

Steam escaping into the air has been observed to be coloured when seen against the sun. Sometimes in that case the sun appears like silver (light blue), blue or green. Mr. Lockyer saw the sun look vivid green through the steam of a little paddle-boat on Lake Windermere. Though the shadow of an ordinary steam jet on a white screen is nearly colourless, yet when it is electrified the shadow becomes of a dark orange-brown colour.

In studying the subject, Mr. Aitken has enclosed the steam jets in tubes. For a jet from a nozzle of one millimètre bore, a tube of seven centimètres diameter and about fifty centimètres long is employed. The steam nozzle should be placed outside the tube and a little to one side, so that the eye can be brought into a line with the axis of the cylinder. This is a beautiful experiment. When the amount of steam, dust, and other conditions are properly proportioned, the colours seen through the tube are very attractive. With ordinary condensation the colour varies from a fine green to lovely blues of different depths. The pale blues equal any sky blue, while the deeper blues are finer than the dark blues seen in the sky, as they have none of the cold hardness of the dark sky blues, but have a peculiar softness and fulness of colours.

Suppose, now, the tube is fitted up pointing to a clouded sky, and that the steam jet, under slight pressure, is blowing through it. If the exit end of the tube be open, very little colour is visible; but if the end of the tube be partially closed with a glass plate to prevent a draught, the tube looks as if filled with a transparent coloured gas. The first decided colour is generally green, then blue of different shades.

If, now, the number of the dust particles in the tube be increased, or the pressure of the steam be increased so as to command some negligent dust particles to seize the moisture and add to the number of cloud particles, thereby making the steam more dense, then the colour seen through the tube also changes. If the colour was green, it now becomes deep blue; and if the ordinary condensation gave blue, the dense condensation (a strange but unavoidable connection of words) produces a dark yellowish-brown. But between the blue and the yellow there is always an intermediate stage, when all colour disappears and the light is simply very much darkened. Condensation of the denser kind may be also produced by passing a flash of electricity through the jet, by a supply of cold air, or by placing an obstruction in front of the nozzle; for there are five ways of producing a denser form of condensation of steam.

From this it is seen that the colour produced by the small drops of water depends on the size of the drops, and the depth of colour on their number. The most probable explanation of these colour phenomena is that they are produced in the same way as the colours in plates, somewhat after the manner Newton thought the colour of the sky was produced. The order of succession of the colours in thin plates is the same as in these condensation phenomena. As no white follows the first blue, it seems probable that the first order of colours is not observed; that the two generally seen are the second and third.

These colour phenomena placed in Mr. Aitken's hands an easy and simple way of estimating, in a rough but useful way, the number of dust particles in the air of our rooms, and sanitary officers might with advantage employ the convenient apparatus. And Mr. Aitken invented the koniscope for the purpose. *Konis* is the Greek for dust, and *skopeo* means "I see"; so the instrument is for detecting the quantity of dust in air by sight—in fact, by the colour observed in the fog produced in the air by artificial means. The instrument consists of an air-pump and a metal tube with glass ends (about the size of the one above described in the experiments). Near one end of the test-tube is a passage by which it communicates with the air-pump, and near the other end is attached a stopcock for admitting the air to be tested. Wet blotting-paper is attached to the inside, to make more uniform the field of colour. The instrument is not nearly so accurate as the dust-counter, but it is cheaper, more easily wrought, and more handy for quick work. All the grades of blue, from what is scarcely visible to deep black-blue, are attached alongside the tube on pieces of coloured glass, and opposite these colours are the numbers of dust particles in the cubic centimètre of the similar air, as determined by the dust-counter. While the number of particles was counted by means of the dust-counter, the depth of blue given by the koniscope was noted, and the piece of glass of that exact depth of blue attached. A metal tube was fitted up vertically in the room in such a way that it could be raised to any desired height into the impure air near the ceiling, so that supplies of air of different degrees of impurity might be obtained. To produce the impurity, the gas was lit and kept burning during the experiments. The air was drawn down through the pipe by means of the air-pump of the koniscope, and it passed through the measuring apparatus of the dust-counter on its way to the koniscope. It may be remarked that by a stroke of the air-pump attached to the koniscope, the air within the test-tube is rarefied and the dust particles seize the moisture in the super-saturated air to form fog particles; through this fog the colour is observed, and the shade of colour determines the number of dust particles in the air. When by the dust-counter the number of dust particles in a cubic centimètre of the air examined amounted to 50,000, the koniscope indicated that colour was just visible; when 80,000 were counted, the depth of colour was said to be "very pale blue"; when 500,000, "pale blue"; when 1,500,000, "fine blue"; when 2,500,000, "deep blue"; and when 4,000,000, "very deep blue."

When making a sanitary inspection, the pure air should be examined first, and the colour corresponding to that should be considered as the normal health colour. Any increase from the depth would indicate that the air was being gradually contaminated, and the amount of increase in the depth of colour would indicate the amount of increase of pollution. Mr. Aitken thinks that the koniscope will be serviceable for sanitary inspectors for investigating questions of ventilation in rooms lighted with gas, and for other purposes.

As an illustration of what this instrument can detect, he gives this experiment, to show how the pollution taking place in rooms by open flames may be traced. The room in which the tests were made was 24 by 17 by 13 feet. The air was examined before the gas was lighted, and the colour in the test-tube was very faint, indicating a clear atmosphere. In all parts of the room this was found the same. A small tube was attached to the test-tube, open at the other end, for taking air from different parts of the room. Three jets of gas were then lit in the centre of the room, and observations at once begun with the koniscope. Within thirty-five seconds of striking the match to light the gas the products of combustion had extended to the end of the room; this was indicated by the colour in the koniscope suddenly becoming of a deep blue. In four minutes the deep blue-producing air was got at a distance of two feet from the ceiling. In ten minutes there was strong evidence of the pollution all through the room. In

thirty minutes the impurity at nine feet from the floor was very great, the colour being an intensely deep blue.

The wide range of the indications of the instrument, from pure white to nearly black-blue, makes the estimate of the impurity very easily taken with it, and as there are few parts to get out of order, it is hoped it may come into general use for sanitary work. Mr. Aitken was quite enchanted with the beautiful colours in his preliminary experiments, but he is even more pleased at the practical benefit which the koniscope may effect when thoroughly adjusted and intelligently used.

THE CLIMATE OF THE CAMBRIAN PERIOD.

By Prof. J. Logan Lobley, F.G.S., &c.

THERE is a widely-spread impression that the state of the surface of the earth and the prevailing climatal and atmospheric conditions of pre-Quaternary geological periods were quite unlike those that now exist, so much so indeed as to be altogether unfitted for the human occupation of the planet.

The vast number of extinct organic forms revealed by palæontological investigation, and the great divergence of many from those now living, as well as the late coming in of new species, have largely contributed to produce this belief; but, perhaps, it has been most encouraged by the fact of the vegetable origin of coal, since it has been thought necessary by some writers to assume such atmospheric and climatal conditions for the production of the Carboniferous flora as would be quite inimical to the existence of man. And yet the records of the rocks conclusively establish the great fact, that not only in Tertiary and Secondary times, but also in Palæozoic times—indeed, in the earliest Palæozoic times—general inorganic conditions were very similar to those of to-day.

As has been said by a recent writer on fossils, when referring to distant geological periods, "Flesh and blood were then what they are now, and fulfilled the same functions. Bones grew then as they grow nowadays. To those bones were attached muscles, which expanded and contracted just as muscles do now. Wings were used for flying, fins and paddles for swimming, legs for walking, teeth for masticating food, just as they are now. In fact, these primitive inhabitants of the antique world, however different in bodily shape from those we see around us now, lived under the same universal laws of physiology as we ourselves do."* To this it may be added, that these animals of the past lived, too, under the same general inorganic conditions as those in which we have our being.

But this conclusion, most momentous and far-reaching though it be, seems strangely overlooked by both text-book and popular writers on geology. It may, therefore, be well to briefly emphasize the undoubted teaching of the facts presented by a study of the Cambrian rocks.

These facts are some petrological and some palæontological.

The Cambrian rocks are not only of vast thickness, but they form extensive areas both numerous and widely dispersed. In the British Islands they are conspicuous in Wales, whence they take their name, in Shropshire, Cumberland, Scotland, Ireland, and the Isle of Man; and on the Continent of Europe we find them in France, Belgium, Germany, Bohemia, and Spain, and far north in Sweden and Norway. In the western continent they form large areas in Canada, Nova Scotia, and the United States; and when we turn to the east we see these ancient rocks in far Cathay, for the Sinisian formation of China was shown by Richthofen to be of Cambrian age.

These enormous accumulations of marine sediment are of very diverse character, presenting different lithological aspects in different areas, and consisting, even in the same area, of beds of greatly differing rocks. There are great masses of sandstones, compacted and cemented aggregations of grains of quartz derived from the destruction of still older quartzose rocks, and there are also thick beds of conglomerates made up of pebbles, every one of which has been a water-rolled angular hard-rock fragment. There are, too, immense accumulations of argillaceous rocks, consisting altogether of materials derived from the decomposition of the felspar of granites or other felspathic rocks, and there are, moreover, in America, calcareous rocks, the material of which is the same as that forming those newer limestones which have been the result of organic action. Volcanic rocks, in addition, are not wanting to furnish further evidence of what were the cosmic conditions of the globe in the Cambrian period.

But over and above all this, there are markings on Cambrian sandstones identical with those now produced by waves and ripples on sheltered shores and shallow-water bottoms, as well as—and these are very significant—cracks and pittings, only ascribable to the action of the sun and rain.

Such are, briefly stated, the main petrological facts of the Cambrian rocks, and from these facts the following conclusions may be drawn:—

Since the whole of the material of which these rocks of enormous thickness and of diverse mineral character has been accumulated by the deposition of derived matter on sea-bottoms exactly as marine sediments are now being accumulated, it follows that those agencies of Nature, which are the controlling forces of the physical cosmos, were acting in the same way as at present.

Not only do we see that the matter of the globe was the same in its chemical combinations and states of aggregation as now, but that the bulk of the water of the globe was in a liquid state, and that therefore the temperature over the greater part of the earth was, as at present, between 32° and 212° Fahr.

The derivation of the material of the sediments required the erosion of land surfaces by water agency, requiring rain, which again required the atmosphere to be charged with varying amounts of water-vapour, increased at one time by evaporation and at another time diminished by condensation. Thus there was rain that formed streams and rivers on the land, that wore down and destroyed rocks, the detritus of which was transported to the sea, in all respects exactly as at present. Thus, too, there were alternations of temperature to produce alternate evaporation and condensation, and those alternations were confined for the most part within very moderate limits as now.

Clouds, too, would form, wax and wane, and, with varying densities of aggregation of the watery particles, assume those beautiful forms we know so well, and float at various elevations in the atmosphere; and when these clouds broke or dissolved, blue skies and bright sunshine would alternate with shade even as now.

Again, the air would be put in motion by the varying temperatures, and consequently winds would sweep the land and ripple the sea, waves would beat upon the shores and roll rock-fragments into smooth rounded pebbles. These winds with the rotation of the earth would take the courses they now have, and so there would be then as now trade-winds and anti-trades as well as cyclones and hurricanes, and the monsoons and calms of the tropics. There would also be ocean currents, that would mingle the waters of the

* Rev. H. N. Hutchinson, "Creatures of Other Days," p. 2.

Cambrian seas as they now bring the heated waters of the Gulf of Mexico to the North Atlantic.

Still further, the sun and moon exerting their attractive force as now would raise a tidal wave that would in the narrow seas give with its ebb broad low-water beaches, and with its flow rolling high-water waves to attack the coast-cliff bases, and still further wear and round the shingle pebbles.

Climate would vary as at present, with latitude and distribution of land and sea, and so all the conditions would be present to give graduated temperatures analogous to those that now in various lands range from tropical heat to Arctic cold.

The seas of the Cambrian period were likewise, as those of our epoch, some deep and some shallow, for both deep-water deposits and shallow-water sediments make up the Cambrian rocks.

And throughout the millenniums of the Cambrian period night would follow day and day would follow night; daylight would lengthen and strengthen, and daylight would shorten and diminish; and in the temperate zones spring, summer, autumn and winter would complete the year, while in the tropics the rainy seasons and the dry seasons would alternate as now.

These conclusions might have been drawn from even the larger and more general phenomena of the Cambrian rocks, but the beds of water-rolled pebbles, the ripple-markings, the sun-cracks, and the rain-pittings confirm such conclusions.

The palæontological evidence—that is, the evidence of fossils—is as conclusive as the petrological evidence with respect to the character of the climatal conditions of the globe prevailing during the period of the deposition of the Cambrian rocks.

Although in the oldest of the Cambrians of the Long-mynds of Shropshire and of North Wales the actual remains of animals are few and obscure, yet the paired or twin perforations in the sandstones can be none other than annelid borings, that tell of the existence of sand-worms, similar to those that abound on our present shores, and so confirm the evidence of tidal beaches furnished by the ripple-marks, sun-cracks, and rain-pittings. Casts of fucoids, too, tell of marine vegetation like that now growing on sea-bottoms.

But when we examine the Cambrians of Pembrokeshire, we find remains of Crustacea of large size, and although the great family, the *Trilobitidæ*, has no representatives in our present seas, yet trilobites in their general organization so closely resembled the lobsters and crabs of the present day that they must have required a generally similar environment. Dean Buckland long since observed that the eyes of trilobites indicate that there was the full light of day when they lived. These wonderful organs of vision were sessile and compound like those of the common crab, though the lenses were round instead of hexagonal as in our crustacean side-walking friend of the sea-shore, but the facets were so numerous that as many as fifteen thousand in each eye existed in some cases. Dr. Henry Woodward thinks the eye of the trilobite may best be compared with that of *Limulus*, and that there is an analogous development of visual organs amongst some of the pelagic *Amphipodæ*, the *Hyperiidæ*, and in a very singular form brought home by the "Challenger," the *Thaumops pellucida*.

In other Cambrian rocks, the Lingula Flags, are abundant remains of *Lingulella*, a genus or sub-genus of a family of Brachiopoda now well represented by the *Lingula chinensis* of eastern Asiatic seas. This is perhaps a more telling fact than the occurrence of an extinct group of Crustacea, for not only was the living body of the animal similar, and therefore suited only to similar general conditions, but the peculiar thin horny shell of the lingula of to-day was exactly represented by the shell of the *Lingulella Davisii* of the Lingula Flags, evidencing similar materials in both the Cambrian and the present sea-waters of the globe, as well as the same physiological powers for its extraction and employment by the mollusc.

Perhaps, however, even a still more striking proof of the general cosmic conditions of the Cambrian period being the same as those of the present epoch is afforded by the occurrence in Cambrian rocks of species of a family of Lamellibranchiata, the Arcidæ, now abundantly represented by well-developed and, so to speak, robust species in our English seas. As I a long time ago pointed out, the Cambrian Arcidæ and the abundance of members of the family now, give a conspicuous proof of the marvellous continuity of biomorphic types, or general organic form and structure, from early geologic times to the present; and that great as is the generally interesting character of this wonderful fact in itself, its significance or indirect teaching is exceedingly great also, for it clearly indicates the continuity of general inorganic conditions which must have existed to allow of the uninterrupted succession of generally similar organisms, all requiring, therefore, a generally similar environment for their existence and welfare, as well as for the development of the type.

From the abundant evidence thus afforded of marine organic existence living in Cambrian times as it does to-day, we cannot doubt that the composition and density of the water of the sea were practically the same as now, and that both the sea and the atmosphere had the same relations to light, the same optic powers—the same absorptive, refractive, and reflective powers—as now.

The teachings, therefore, of stratigraphical geology, both petrological and palæontological, tell us in no uncertain way that the general inorganic conditions on the surface of the globe were during the Cambrian period very much the same as they are to-day. So clear and unmistakable is the evidence that we can with great confidence picture to ourselves the ancient Cambrian world.

We can see, as it were, its lands and its seas, its spreading plains and elevated uplands, and its broad and deep seas, with their shallower bays and gulfs. On the land, too, are rushing torrents, rippling streams, and larger and smoother flowing rivers, carrying eroded material to the Cambrian ocean, fringed by sandy shores and shingly beaches. And the sky above is now an unblemished azure, now flecked with cirrus, and now dark with nimbus. Rain falls, winds blow, tides ebb and flow, and we can see the broad expanse of waters in their calm majesty or angry with storm and tempest rolling mighty waves upon the Cambrian strand, and we can think of the millions of splendid sunrisings and gorgeous sunsets, and almost feel the heat of the noontide summer sun or the cold of the midwinter night.

We can even look through the clear salt water on to the ocean bed, and see the groves of algæ, with the trilobites and molluscs peopling those ancient seas, while along their coasts volcanic fires at intervals break forth, and lavas are outpoured that cover the surrounding rocks with basaltic or trachytic coatings.

But save for these volcanic outbursts, the crash of thunder, and the roar of wind and wave, a silent world it was. No lowing herds or roaring beasts of prey were on the land, and no birds sang their songs either on tree-top or high upon the wing. And how desolate was the unnavigated sea, for whales and porpoises, seals and sharks, and flying-fishes were not in its waters, and no sea-bird's mew was heard, for no stormy petrel, gull, or penguin was upon its surface.

XUM

This is no fancy picture of a world of the imagination, but a picture of an actual world, a world that has been, a world that lasted millions of years, and a world that, unlike the airy fabric of a vision, has left many wrecks behind.

THE FACE OF THE SKY FOR NOVEMBER.

By HERBERT SADLER, F.R.A.S.

SUNSPOTS and faculæ show few signs of decrease. Conveniently observable minima of Algol occur at 0h. 11m. A.M. on the 8th, 9h. 0m. P.M. on the 10th, 5h. 49m. P.M. on the 13th, and 10h. 42m. P.M. on the 30th.

Mercury is not favourably situated for observation during the first half of the month, being too near the Sun. After this date his position rapidly improves. On the 19th he rises at 5h. 47m. A.M., or 1h. 40m. before the Sun, with a southern declination of 12° 54′, and an apparent diameter of 8·2″, $\frac{38}{100}$ths of the disc being illuminated. On the 24th he rises at 5h. 37m. A.M., or nearly two hours before the Sun, with a southern declination of 13° 30′, and an apparent diameter of 7·0″, about half the disc being illuminated. On the 29th he rises at 5h. 43m. A.M., or two hours before the Sun, with a southern declination of 15° 15′, and an apparent diameter of 6¼″, $\frac{67}{100}$ths of the disc being illuminated. He is at his greatest western elongation (20°) on the afternoon of the 27th. There will be a transit of the planet across the Sun's disc on the afternoon of the 10th, unfortunately under very unfavourable conditions for observation in England, though things improve as we go west. At Greenwich external contact at ingress takes place at 3h. 55m. 40s. P.M., at an angle for direct image of 98° from the North Pole towards the east, and internal contact at 3h. 57m. 23s. The Sun sets at 4h. 16m. P.M. While visible Mercury describes a direct path in Libra, being near μ on the 23rd.

Venus is too near the Sun for observation in November. She is in superior conjunction with the Sun on the 30th.

Mars is an evening star, and is admirably situated for observation. He rises on the 1st at 4h. 3m. P.M., with a northern declination of 7° 59′, and an apparent diameter of 20·2″, the phase on the *n f* limb only amounting to 0·2″. On the 7th he rises at 3h. 30m. P.M., with a northern declination of 7° 51′, and an apparent diameter of 19·3″, the phase amounting to 0·3″. On the 12th he rises at 3h. 10m. P.M., with a northern declination of 7° 51′, and an apparent diameter of 18·4″, the phase amounting to about 0·5″. On the 19th he rises at 2h. 40m. P.M., with a northern declination of 8° 1′, and an apparent diameter of 17¼″, the phase amounting to about 0·7″. On the 26th he rises at 2h. 10m. P.M., with a northern declination of 8° 23′, and an apparent diameter of 15¾″, the phase amounting to 0·9″. On the 30th he rises at about 1h. 55m. P.M., with a northern declination of 8° 40′, and an apparent diameter of 15¼″, the phase amounting to nearly 1″. Mars is stationary among the stars on the 22nd, and during the first three weeks of November pursues a short retrograde path to the west of o Piscium; after that, he retraces his steps.

Jupiter is an evening star in the sense of rising before midnight. He rises on the 1st at 7h. 30m. P.M., or nearly 3h. after sunset, with a northern declination of 22° 59′, and an apparent equatorial diameter of 43″. On the 6th he rises at 7h. 8m. P.M., or 2¾h. after sunset, with a northern declination of 23° 0′, and an apparent equatorial diameter of 43·1″. On the 12th he rises at 6h. 42m. P.M., with a northern declination of 23° 1′, and an apparent equatorial diameter of 44⅓″. On the 19th he rises at 6h. 12m. P.M., with a northern declination of 23° 3′, and an apparent equatorial diameter of 45·1″. On the 30th he rises at 5h. 25m. P.M., or 1½h. after sunset, with a northern declination of 23° 7′, and an apparent equatorial diameter of 46″. During the month he pursues a short retrograde path in Gemini, to the north of μ and η Geminorum. The following phenomena of the satellites occur while the Sun is 8° below and Jupiter 8° above the horizon:—On the 1st an occultation reappearance of the second satellite at 9h. 11m. P.M. On the 2nd a transit ingress of the shadow of the first satellite at 4h. 36m. A.M.; a transit ingress of the satellite at 5h. 41m. A.M. On the 3rd an eclipse disappearance of the first satellite at 1h. 45m. 59*s*. A.M.; its occultation reappearance at 5h. 4m. A.M.; a transit ingress of the shadow of the first satellite at 11h. 4m. P.M. On the 4th a transit ingress of the first satellite at 0h. 8m. A.M., a transit egress of its shadow at 1h. 20m. A.M., a transit egress of its shadow at 2h. 24m. A.M.; an eclipse disappearance of the third satellite at 5h. 10m. 18s. A.M.; an occultation reapearance of the first satellite at 11h. 31m. P.M. On the 5th an eclipse disappearance of the second satellite at 5h. 42m. 7s. A.M.; a transit egress of the second satellite at 8h. 51m. P.M. On the 6th a transit ingress of the second satellite at 11h. 50m. P.M. On the 7th a transit ingress of the second satellite at 1h. 53m. P.M., a transit egress of its shadow at 2h. 25m. A.M.; a transit egress of the satellite itself at 4h. 29m. A.M.; a transit egress of the shadow of the third satellite at 10h. 0m. P.M., a transit ingress of the satellite itself at 11h. 19m. P.M. On the 8th a transit egress of the third satellite at 2h. 7m. A.M.; an occultation reappearance of the second satellite at 11h. 33m. P.M. At midnight on the 10th a 10½ magnitude star will be between the second satellite and the planet, 1¼′ *f* Jupiter and 2′ north. On the 11th a transit ingress of the shadow of the first satellite at 0h. 58m. A.M., a transit ingress of the satellite at 1h. 55m. A.M., a transit egress of the shadow at 3h. 14m. A.M., a transit egress of the satellite at 4h. 11m. A.M., and an eclipse disappearance of the first satellite at 10h. 8m. 10s. P.M. On the 12th an occultation reappearance of the first satellite at 1h. 19m. A.M.; a transit ingress of the first satellite at 8h. 22m. P.M., a transit egress of its shadow at 9h. 42m. P.M., and a transit egress of the satellite at 10h. 38m. P.M. On the 14th a transit ingress of the shadow of the second satellite at 2h. 25m. A.M., a transit ingress of the satellite at 4h. 13m. A.M., a transit egress of its shadow at 5h. 0m. A.M.; a transit ingress of the shadow of the third satellite at 11h. 17m. P.M. On the 15th a transit egress of the shadow of the third satellite at 2h. 0m. A.M., a transit ingress of the satellite at 2h. 50m. A.M., and its transit egress at 5h. 37m. A.M.; an eclipse disappearance of the second satellite at 9h. 35m. 21s. P.M. On the 16th an occultation reappearance of the second satellite at 1h. 54m. A.M. On the 17th an eclipse disappearance of the first satellite at 5h. 33m. 31s. A.M.; a transit egress of the second satellite at 7h. 59m. P.M. On the 18th a transit ingress of the shadow of the first satellite at 2h. 52m. A.M., a transit ingress of the satellite at 3h. 42m. A.M., a transit egress of the shadow at 5h. 8m. A.M, and of the satellite at 5h. 58m. A.M. At midnight on the 18th a 10½ magnitude star will be between the second satellite and the planet, ½′ *p* Jupiter and 20″ north. On the 19th an eclipse disappearance of the first satellite at 0h. 2m. 1s. A.M., its occultation reappearance at 3h. 5m. A.M., a transit ingress of the shadow of the satellite at 9h. 20m. P.M., a transit ingress of the satellite itself at 10h. 8m. P.M., and a transit egress of its shadow at 11h. 36m. P.M. On the 20th a transit egress

of the shadow of the first satellite at 0h. 24m. A.M., and its occultation reappearance at 9h. 31m. P.M. On the 21st a transit ingress of the shadow of the second satellite at 5h. 0m. A.M., a transit ingress of the satellite itself at 6h. 32m. A.M. On the 22nd a transit ingress of the shadow of the third satellite at 3h. 15m. A.M., its transit egress at 6h. 0m. A.M., and a transit ingress of the satellite at 6h. 15m. A.M. On the 22nd at midnight a $10\frac{1}{2}$ magnitude star will be 1·6′ *p* and 1·7′ south of the planet, between the third satellite and Jupiter. On the 23rd an eclipse disappearance of the second satellite at 0h. 10m. 34s. A.M., and its occultation reappearance at 4h. 12m. A.M. On the 24th a transit ingress of the second satellite at 7h. 40m. P.M., a transit egress of its shadow at 8h. 53m. P.M., a transit egress of the satellite at 10h. 17m. P.M. At midnight a $10\frac{1}{2}$ magnitude star will be 70″ *p* Jupiter and 20″ north, being between the second and third satellites, and closely *p* the second. On the 25th a transit ingress of the shadow of the first satellite at 4h. 46m. A.M., and of the satellite itself at 5h. 27m. A.M.; an eclipse reappearance of the third satellite at 7h. 42m. 47s. P.M., its occultation disappearance at 7h. 43m. P.M., and its occultation reappearance at 10h. 31m. P.M. On the 26th an eclipse disappearance of the first satellite at 1h. 55m. 59s. A.M., and its occultation reappearance at 4h. 50m. A.M.; a transit ingress of the shadow of the first satellite at 11h. 14m. P.M., and of the satellite itself at 11h. 53m. P.M. At midnight a $10\frac{1}{2}$ magnitude star will be 1·1′ *p* and 1·1′ south of Jupiter, between the fourth satellite and the planet. On the 27th a transit egress of the shadow of the first satellite at 1h. 30m. A.M., and of the satellite itself at 2h. 9m. A.M.; an eclipse disappearance of the first satellite at 8h. 24m. 27s. P.M., and its occultation reappearance at 11h. 16m. P.M. At midnight an 8·5 magnitude star will be $\frac{3}{4}$′ *p* the fourth satellite. On the 28th a transit egress of the shadow of the first satellite at 7h. 59m. P.M., and of the satellite itself at 8h. 35m. P.M. At about 10h. P.M. on the 29th a $10\frac{1}{2}$ magnitude star will be centrally occulted by the planet. On the 30th an eclipse disappearance of the second satellite at 2h. 45m. 43s. A.M., and its reappearance from occultation at 6h. 28m. A.M.

Both Saturn and Uranus are, for the observer's purposes, invisible.

Neptune is an evening star, and is very well situated for observation. On the 1st he rises at 6h. 10m. P.M., with a northern declination of 21° 8′, and an apparent diameter of 2·7″. On the 30th he rises at 4h. 17m. P.M., with a northern declination of 21° 2′. During November he pursues a retrograde path in Taurus, from the south to the south-west of ι Tauri. A map of the small stars near his path will be found in the *English Mechanic* for September 7th, 1894. At the beginning of the month he is only about 20′ south of ι Tauri.

November is a very favourable month for shooting stars. The most marked displays are the Leonids on November 13th and 14th, the radiant point being in R.A. 10h. 0m., and northern declination 23°. The radiant point rises at about 10h. 15m. A.M., but the Moon will be full at the time. The Andromedas occur on the 27th, the radiant point being in R.A. 1h. 40m., and northern declination 43°.

The Moon enters her first quarter at 3h. 16m. P.M. on the 5th; is full at 7h. 49m. A.M. on the 13th; enters her last quarter at 2h. 8m. A.M. on the 20th; and is new at 8h. 54m. A.M. on the 27th. She is in apogee at 10h. P.M. on the 4th (distance from the earth 251,320 miles), and in perigee at 8h. P.M. on the 16th (distance from the earth 228,190 miles). At 4h. 29m. P.M. on the 7th (8m. after sunset) the $6\frac{1}{3}$ magnitude star 70 Aquarii will disappear at an angle of 42°, and reappear at 5h. 42m. P.M. at an angle of 254°. On the evening of the 13th the full Moon will pass through the Pleiades. At 7h. 38m. P.M. the $4\frac{1}{4}$ magnitude star 23 Tauri (Merope) will make a near approach (8′ distance) to the northern limb at an angle of 336°; at 8h. 9m. P.M. the 3rd magnitude star η Tauri (Alcyone) will make a near approach (5′ distance) to the northern limb at an angle of 336°; at 8h. 29m. P.M. the $3\frac{3}{4}$ magnitude star 27 Tauri (Atlas) will disappear at an angle of 21°, and reappear at 9h. 14m. P.M. at an angle of 290°; at 8h. 50m. P.M. the $5\frac{1}{2}$ magnitude star 28 Tauri (Pleione) will disappear at an angle of 347°, and reappear 13m. later at an angle of 324°. At 7h. 9m. P.M. on the 15th the $4\frac{1}{2}$ magnitude star 136 Tauri will disappear at an angle of 119°, and reappear at 7h. 50m. P.M. at an angle of 224°. At 0h. 3m. A.M. on the 17th the $5\frac{1}{2}$ magnitude star 47 Geminorum will disappear at an angle of 162°, and reappear at 1h. 6m. A.M. at an angle of 249°. At 2h. 0m. A.M. on the 20th the $6\frac{1}{4}$ magnitude star 34 Leonis will disappear at an angle of 159°, and reappear at 2h. 46m. A.M. at an angle of 251°. At 5h. 57m. A.M. on the 23rd the $5\frac{3}{4}$ magnitude star B.A.C. 4531 will make a near approach at an angle of 214°.

Chess Column.

By C. D. Locock, B.A.Oxon.

Communications for this column should be addressed to C. D. Locock, Burwash, Sussex, and posted on or before the 12th of each month.

Solution of Problem (B. G. Laws).

Key-move.—1. K to Kt4.

If 1. . . . K to K5, 2. Q to B2ch.
1. . . . K to K3, 2. Q to B6ch.
1. . . . P to K3, 2. Q to Qsqch.
1. . . . K to Q5, etc. 2. Q to Q7ch.

Correct Solutions received from W. Willby, H. S. Brandreth, H. F. Culmer, A. G. Fellows, White Knight.

Solution of Conditional Problem (W. De Morgan).

Key-move.—1. B to K7.

If 1. . . . R×R, 2. B to B8, and 3. Kt to R6.
1. . . . R to Q3, 2. B to B8, Kt×Kt, 3. B×Kt.
1. . . . R to KB3, 2. R×Kt mate.
1. . . . R×B, 2. R to KB6 mate.

[Had there been no White Pawn at QR3, Black could play R to Kt3, threatening Kt to R6ch.]

Correct Solution received from W. Willby.

J. J. A.—Your solution to No. 1 arrived too late to acknowledge last month. The other solution was incorrect.

J. E. Gore.—Thanks for the problems. In No. 1 the key is too obvious, the piece moved being obviously useless where it stands. Could you not find a better key? The Pawn at Kt5 seems unnecessary. No. 2 is clearly solved in one move by 1. Kt to B5ch. There is no solution in two moves, on account of the check of the Black Rook. Of course a second key is a fatal defect. The problem referred to was inserted without due examination.

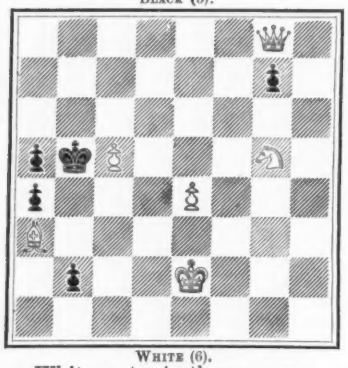
A. C. Challenger.—The problems received are good as usual. We shall be glad to publish them shortly.

A. G. Fellows.—Many thanks for the two problems, which will probably appear in the next number but one. It is to be feared, however, that most of our solvers will think them too difficult to attempt.

PROBLEM.

By Mrs. W. J. BAIRD.

BLACK (5).



WHITE (6).

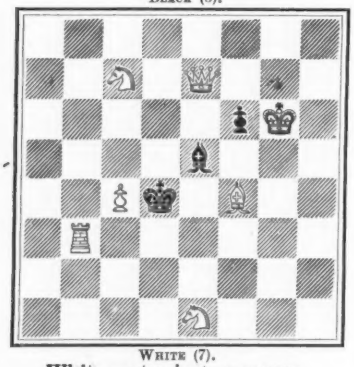
White mates in three moves.

PROBLEM.

By C. D. LOCOCK.

(A modification of one by Mrs. Baird.)

BLACK (3).



WHITE (7).

White mates in two moves.

PAWNS AND THEIR WEAKNESSES.

As it is probable that the majority of match games won by one first-class player from another depend for their result on the weakness of one or more Pawns, it may be worth while to consider briefly the particular weaknesses to which all Pawns are more or less liable. Such weaknesses may be either temporary or permanent. To the latter category belong *Pawns by their position liable to capture*, and especially—

I. *Isolated Pawns.*—The weakness here is obvious. A Pawn which cannot be supported by another Pawn is evidently subject to the concentrated attack of hostile pieces. The disease is aggravated if the opponent has no Pawn on the same file; for he can use the open file to double his Rooks on the Pawn in front, preventing its advance meanwhile either by blocking it with a piece, or by means of Pawns on the adjacent files. *Doubled* and isolated Pawns are usually indefensible, the owner being unable to defend them from behind with his Rooks. Of course, an isolated Pawn may be strong through the accidental peculiarities of the position. This is often the case with a well-supported Pawn at K5 or Q6, when the opponent's QP is unmoved; but *cæteris paribus*, and especially in an end-game, isolation in Pawns is a dangerous and usually incurable disease.

II. *Pawns too far advanced.*—Another generally permanent weakness, for the Pawns cannot retrace their steps, though in some cases it may be possible for adjacent Pawns to advance to their support. The weakness of advanced Pawns lies in their inability to advance further if attacked. Even if they cannot be captured they can be broken up and exchanged by the adverse Pawns, the opponent having the power of choosing his own time for the operation. If the advanced Pawn be a passed Pawn and well supported, of course the case is different; or if all the Pawns on that wing are completely blocked. In that case the advanced Pawns have usually the best position owing to the cramping effect which they exercise. Moreover, in an end-game a piece may be sacrificed for one of the opposing Pawns, in order to queen the advanced Pawn.

In a certain sense it may be stated that *every moved Pawn* is weaker than if it stood on its original square, for it loses the powerful option of moving either one or two squares, according to circumstances; but this axiom cannot, of course, be pushed to extremes.

(To be concluded.)

CHESS INTELLIGENCE.

Mr. Lasker is now in England, and has been giving simultaneous performances at various clubs. He has written to Mr. Steinitz announcing that his engagements do not permit him to play the much discussed return match till next October. The year's interval will, of course, be all in favour of the younger player. While Mr. Lasker was in Leipsic, attempts were made to arrange a match between him and Dr. Tarrasch; but Mr. Lasker very naturally replied that he could not engage in any match of importance until after his return match with Mr. Steinitz.

It is stated, on the authority of the Liverpool players themselves, that they are more than likely to lose their correspondence match with Mr. Steinitz. One game they have apparently given up as lost, and would not be sorry to draw the other, in which they seemed at one time to have some attack.

A match at Glasgow between the Liverpool and Glasgow Chess Clubs resulted in a win for Liverpool by $6\frac{1}{2}$ to $4\frac{1}{2}$, one game being left undecided.

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